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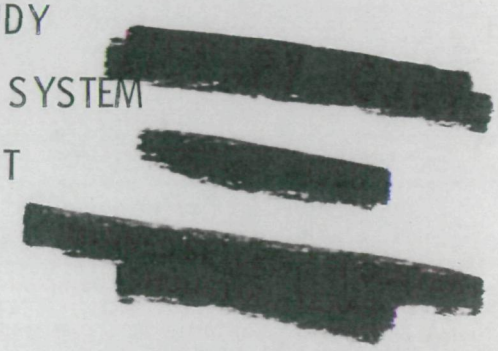
SACRAMENTO PLANT

RESTART CAPABILITY STUDY
APOLLO SERVICE PROPULSION SYSTEM
ELECTRICAL HARNESS TEST



Prepared Under
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Report 4808-FP4

RESTART CAPABILITY STUDY

APOLLO SERVICE PROPULSION SYSTEM

ELECTRICAL HARNESS TEST

Prepared Under
Contract NAS9-4808

For

MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Houston, Texas

AEROJET-GENERAL CORPORATION
Liquid Rocket Operations
Sacramento, California

~~Available to NASA Offices and Research Centers Only.~~

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FOREWORD

This report presents the detailed results of a test program sponsored by the National Aeronautics and Space Administration - Manned Spacecraft Center (NASA-MSC) on the Electrical Harness of the Apollo Service Module Propulsion System. It encompasses the work accomplished under Phase IV, Electrical Harness Test, and was prepared in accordance with Section C9.3 of the statement of work for Contract NAS9-4808, "Apollo Service Propulsion System Restart Capability Study."

The report was prepared by E. R. White and W. R. Krause of the Apollo Applications Program, Liquid Rocket Operations, Aerojet-General Corporation, Sacramento, California. Testing and analysis were performed under the direction of E. R. White, project engineer, with W. R. Krause as the engineering manager. General supervision was provided by C. E. Teague, program manager.

ABSTRACT

A test program was conducted to evaluate the structural and electrical integrity of the Apollo SPS electrical harness in a simulated space environment while subjecting it to the thermal, vibration, and gimbaling effects associated with 27 firings of a 90-day mission.

The basic test program consisted of subjecting two harness assemblies to a vacuum of 10^{-6} torr and a temperature of +30°F for 90 days. Twenty-seven engine firings were simulated during this period by subjecting the harness to vibration levels representative of an engine firing, by increasing the harness temperature to +200°F to simulate engine heat input, and by oscillating the test fixture to simulate engine gimbaling.

A complete harness acceptance test including dielectric, insulation resistance, and continuity tests was conducted before and after the 90-day test. In addition, continuity checks were made through each of the electrical circuits during each of the simulated firings.

None of these tests disclosed any discrepancies; consequently, the SPS electrical harness is considered acceptable for AAP missions.

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I. INTRODUCTION

The report presented herein describes the Phase IV test of the Apollo Service Module Engine Electrical Harness Assembly. The test was conducted to detect any deficiencies of the current harness assembly design which could be revealed during a simulated 90-day mission with appropriate environmental and duty cycle requirements.

II. SUMMARY

The Phase IV test consisted of subjecting the engine electrical harnesses to a simulated mission duty cycle of 90 days duration while maintaining the harnesses in a pressure environment of 10^{-6} torr or less. At specific periods during the 90-day test the harnesses were vibrated and simultaneously flexed to simulate the firing vibration and gimbal movement which would be experienced on an actual mission. The harnesses were also subjected to temperature conditioning throughout the 90-day test. Following each vibration and flexure period the harnesses were heated to simulate the temperature increase associated with an engine firing. During the long coast periods the harnesses were cooled to represent the thermal condition to which the harnesses would be subjected on an actual mission. The harness circuits were monitored for short or open circuits before, during, and after each simulated firing.

The formal test was started on 10 November 1965 and was finished on 16 February 1966. The actual elapsed time exceeded 90 days to compensate for a few short periods when the environmental chamber pressure exceeded the specified maximum. Minor problems were experienced during the course of the test with the gimbaling position micro switches, vacuum cell leaks, overheated gimbaling solenoids, and maintaining the proper coast temperatures during periods when test

II, Summary (cont.)

personnel were not on duty. However, all problems were satisfactorily resolved without interrupting the test.

Following completion of the test, the harnesses were subjected to a repeat of their acceptance test to determine if any degradation had occurred. The results were satisfactory in that there was no functional degradation. The only discrepancies noted were minor fraying of the external fiberglass braid in several places caused by chafing during the test and damaged knurling on two of the electrical plugs. The damage to the plugs was apparently caused by use of an improper tool during installation or removal of the harnesses from the test facility. No significant degradation was noted in any of the harness electrical circuits.

Both harnesses and their log books were shipped to NASA-MSC in an "as is" condition on 7 April 1966, AGC Shipper No. 02348.

III. TECHNICAL DISCUSSION

A. HARNESS DESCRIPTION

The Apollo Service Module Engine Electrical Harness Set consists of two harness assemblies (AGC P/N's 712173 and 712174) which transmit redundant electrical power to the propulsion system; namely to the solenoid valves in the pneumatic actuation system of the bipropellant valve and to the pitch and yaw gimbal actuators. The harness assemblies are also used to carry instrumentation signals from the propulsion system.

The electrical harness assemblies subjected to test were of the Block II configuration. These harness assemblies incorporate connectors of the wedge-seal design ranging in size from 3-pin to 35-pin. The interconnecting wiring is

III, A, Harness Description (cont.)

16 and 20 gage multistrand conductors with 2, 3, and 4 conductors twisted together. RFI shielding is incorporated on all conductors which carry instrumentation signals (except temperature sensors) with the shielding terminated at pins within the connectors. The wiring bundles are enclosed in a stainless steel braid which is attached to an anodized aluminum adapter at the connectors. Teflon-impregnated fiberglass yarn is woven over the stainless steel braid.

The particular harness assemblies selected to be tested for this program were fabricated at the Aerojet-Downey facility as serial number 0000034. They were acceptance-tested at the Aerojet-Sacramento plant per Specification AGC-46726 prior to the start of the test. The operations performed in accordance with this specification consisted of a dielectric strength test, an insulation resistance test, and an electrical continuity test. The dielectric strength test was accomplished on each circuit of the harness utilizing a hi-pot tester and a voltage of 1050 $\pm$ 20 VAC. The maximum allowable current flow during this test is 2 milliamperes. A megohmeter and a test voltage of 500 VDC were used to perform the insulation resistance test. The minimum resistance allowable for each circuit during this test is 100 megohms. The final phase of the acceptance test consisted of checking the electrical continuity of each circuit with an ohmeter. Maximum resistance allowable during this test is 0.5 ohms.

B. TEST REQUIREMENTS

The Phase IV testing requirements consisted of subjecting the harness assemblies to a simulated 90-day mission duty cycle while maintaining them at a pressure of 10^{-6} torr or less. Table 1 presents the schedule of simulated firings and coast periods associated with the hypothetical mission duty cycle. A

III, B, Test Requirements (cont.)

simulated firing is defined as a period of harness flection through an angle of 7° at a rate of 2 cycles per second while being subjected to vibration in accordance with the requirements of Table 2. Temperature conditioning per Figure 1 was also a requirement.

It was agreed with NASA-MSC prior to the start of the test that the schedule in Table 1 would be adjusted as necessary to allow conducting of the simulated firings and their associated heat cycles during normal working shifts only. Interrupted heat cycles would be continued on the next working shift. Since heat lamps were to be used to heat the harness, it was also agreed to turn the lamps off during vibration and gimbaling operations when heat cycles and simulated firings overlapped to prevent damage to the lamp filaments. While reviewing the original NASA temperature requirements for the test, it was found that connectors P-8 and P-22, used in conjunction with the chamber throat temperature sensors, could conceivably reach 370°F. Since this temperature is above the melting point of the 60-40 solder used in the connector fabrication, it was agreed to delete simulation of this thermal condition and that a design change be recommended if a review of firing data indicated that the temperature of the connectors actually reached this value.

C. TEST FACILITY AND STE DESCRIPTION

The test was conducted at the Aerojet-Sacramento Liquid Rocket Operations Test Division Cryogenics Laboratory. This test facility utilizes a vacuum chamber 6 feet in diameter and 9 feet long. The vacuum pumping system has three pumps, a Beech-Russ Model 150 mechanical roughing pump, a Duo-Seal CVC Model KS-600 diffusion pump, and a Duo-Seal CVC Model PMC 50,000 diffusion pump. This

III, C, Test Facility and STE Description (cont.)

pumping system was capable of maintaining the required pressure of 10^{-6} torr or less in the chamber except for periods while the harness was being heated. Photographs of the chamber and pumping system, the chamber control console, and the instrumentation utilized are included as Figures 2, 3, and 4. The chamber has a Pyrex window for observation and flanged openings with electrical connectors for transmission of control and instrumentation signals through the chamber walls.

The facility has strip chart recorders, a recording oscillograph, and a high resolution tape recorder to provide the necessary instrumentation recording requirements.

The test requirements dictated the design of the Special Test Equipment (STE). The STE consisted of a hinged platform to support the harnesses with four integral electrical solenoids to flex the platform and the attached harnesses, a vibration exciter to provide the input vibration, and infra-red lamps to heat the harnesses. The support platform, which was designated to be very rigid to insure that its resonant frequency would be well above the maximum frequency of the random vibration input, was mounted to the vibration exciter output flange and transmitted the vibration to the harnesses through support clamps. The platform was designed to support the harnesses in a two dimensional configuration with the vibration being supplied in only one axis. The support clamps were located at the normal engine installation positions. Brackets were also used to mount the harness connectors rigidly to the support platform. The harnesses are shown mounted on the platform in Figures 5 and 6 and installed inside the chamber in the test configuration in Figures 7 and 8.

III, C, Test Facility and STE Description (cont.)

The most important consideration in the design of the STE was the requirement for it to operate for the 90-day period at a pressure of 10^{-6} torr while being subjected to heat cycles. The electrical equipment armature insulation was considered particularly vulnerable to this environment.

The solenoids selected to flex the harness during simulated firings were Model 2-20-C, manufactured by the West Coast Electrical Manufacturing Company. The armature insulation used in their manufacture was "200 Pedigree Clear Heat Baking Varnish" manufactured by the P. D. George Co. Design calculations indicated two solenoids could adequately operate the gimbaling platform; however, four units were installed as a safety factor.

The vibration exciter used was a Model C-10, manufactured by M-B Electronics, New Haven, Connecticut. The armature insulation used in its manufacture was General Electric "Formvar". In addition to the problem of the unknown vacuum capability of the armature design, the exciter also contained neoprene which loses its plasticizers and becomes extremely brittle at 10^{-6} torr. To prevent failure of the exciter the accessible neoprene surfaces were covered with a protective coating of Dow Corning High Vacuum Lubricant. Since the exciter design is normally air-cooled and vacuum operating temperatures were unknown, a thermocouple was installed on the unit to provide a shutdown signal in the event of overheating. No previous history of the selected vibration exciter or solenoid designs having been operated at 10^{-6} torr was available from their manufacturers; however, it was believed that the units would be suitable for the required duty cycle. As a final protective measure the entire vibration exciter was covered with a plastic bag which exposed the unit to the vacuum chamber environment through a small opening and presented a possible means of maintaining a lesser vacuum in the immediate vicinity of the armature.

III, C, Test Facility and STE Description (cont.)

The harnesses were heated by ten 250-watt infra-red heat lamps manufactured by Westinghouse. The lamps were mounted on a support framework and positioned so that their radiation was directed upon the harnesses from a distance of 9 inches and in the locations shown in Figures 9 and 10. The voltage to the lamps was adjustable through a "Variac" in order to simulate the required heating cycles.

The harness support and gimbaling platform was constructed of aluminum grating with hinges to permit flexing of the harness. Stanchions were mounted to the platforms adjacent to the harnesses. The positions of the stanchions were selected by examining an assembled engine and noting each harness position that could be made to contact the engine by physically forcing it toward the engine. A stanchion was placed at each of the noted harness positions and at a distance from the harness representative of the observed engine harness installation.

The harness was cooled by circulating cold nitrogen in the outer shell of the vacuum chamber. An automatic temperature controlled system was installed during the test to maintain the required coast temperatures. A schematic of the automatic temperature control system is shown in Figure 11.

D. INSTRUMENTATION

The instrumentation required for this test consisted of circuitry for monitoring each of the harness circuits, thermocouples for measuring the harness temperature, accelerometers for measuring the vibration levels, position switches for verifying gimbaling, and pressure measurements of the chamber pressure. The harness circuits, accelerometers, and position switches were monitored during simulated firings. The harness temperature and the chamber pressure were monitored continuously.

III, D, Instrumentation (cont.)

A typical circuit used to monitor the harness circuits is shown in Figure 12. Seventeen of these circuits were monitored using oscillograph galvanometers for the full duration of each simulated firing.

Thermocouples were attached to the harness at the locations shown in Figures 9 and 10. Because of thermocouple channel limitations only sixteen positions could be monitored simultaneously. Those positions identified as TC-1 thru 8 and TC-13 thru 20 were monitored during simulated firings 001 through 016 (until 5 January 1966). For the remainder of the test TC-9 and TC-11 replaced TC-4 and TC-8. Each of the monitored thermocouples was sampled every two minutes and was recorded on a strip chart recorder. A thermal analysis of the test setup was conducted to substantiate the validity of the temperature measurements. The calculations made for this analysis are presented in Appendix "A". The analysis, using a very conservative approach, indicated that the temperature registered by the thermocouple was within 25° of the actual harness surface temperature.

Accelerometers were attached to the gimbaling platform to verify the vibration environment. Two of the accelerometers were recorded on an Ampex tape recorder and a third was recorded on an X-Y plotter at the vibration control console. The accelerometer data which were recorded on tape were analyzed by a Honeywell Analyzer which reduces the vibration data to the required format for presenting spectral density.

Position switches were mounted to the gimbaling platform to show the position of the hinged portion of the platform. Two switches were adjusted to be actuated when the platform was in the lowered (normal) position and two were

III, D, Instrumentation (cont.)

mounted so that they were actuated when the hinged portion of the platform was in the raised (7° above normal) position. One switch for each position was monitored and the remaining redundant switches were maintained as backup instrumentation.

The pressure of the vacuum tank was measured by two methods. The primary system was an ionization gage, Model IGC-60-32, manufactured by the Vacuum Products Division of F. J. Cooke, Incorporated, South Norwalk, Connecticut. The secondary system was a "Redhead Gage Control", Type 752, manufactured by NRC Equipment Corporation of Newton, Massachusetts.

E. TEST SUMMARY

1. Chronological Log

The formal test was started at 1000 hours on 10 November 1965. A list of the simulated engine firings and some of the pertinent information concerning them is presented as Table 3. Continuous plots of chamber pressure and harness temperature for the test are presented as Figures 13, 14, and 15. Figures 13 and 14 both represent the pressure variations in the chamber throughout the test program. However, although Figure 13 shows the peak pressures encountered, the scale used prevents an accurate reading in the lower pressure range. Figure 14, which has an expanded lower pressure scale, is included to provide accurate low pressure data. Use of the two figures provides valid data for both peak and low pressure ranges. The reduced vibration data for a typical simulated firing is presented as Figure 16. Since the vibration input for all the simulated firings was the same, and to reduce the bulk of this report, additional vibration plots are included only as necessary for clarity.

III, E, Test Summary (cont.)

Approximately 8 hours after the start of the test the chamber pressure increased to a value above 1 x 10^{-6} torr (the contractual maximum). The following day (11 November 1965) the pressure was again reduced to a level below 10^{-6} torr and simulated firing 1.2-02-DPE-001 was conducted after an accumulated period of 9.4 hours below the contractual maximum pressure. A "heat cycle" followed the test per Figure 1. During the heat cycle, the chamber pressure again exceeded 10^{-6} torr, probably because of outgassing of the equipment and chamber walls.

On 12 November 1965 a leak developed at the inner seal of the chamber access door. This door incorporates redundant seals and the outer seal was activated by evacuating the volume between the seals. This "fix" was effective since no further leakage at the access door was noted.

During the heat cycle portion of simulated firing 1.2-02-DPE-002, which was conducted on 15 November 1965, the pressure again exceeded 10^{-6} torr.

During simulated firings 1.2-02-DPE-003 thru 008, all of which were conducted on 16 November 1965, the vacuum chamber was cooled by admitting cold nitrogen into the tank outer jacket in an attempt to reduce the outgassing of the equipment and the vessel walls during the heat cycle. For this series of tests, the heat cycle was started after the third and continued through the eighth simulated firing. This procedure was successful as the pressure was maintained below 10^{-6} torr. Cooling the vessel walls with nitrogen also had the undesirable effect of reducing the effectiveness of the heat lamps and the temperatures attained during the heat cycle were lower than desired. Since the heat cycle was not completed on 16 November, it was continued on 17 November without chilling the vessel walls. During this portion of the heat cycle the pressure exceeded 10^{-6} torr for a short period.

III, E, Test Summary (cont.)

A temperature of 350°F was recorded on the solenoids during the fourth (250-sec duration) simulated firing. The maximum design operating temperature of the solenoids is 200°F. On this same run it was noted that the position switch which is actuated by the hinged portion of the gimbaling platform when it is in the "up" position was operating intermittently. On all subsequent runs the redundant switch was monitored for an indication of gimbaling.

During the first 200 elapsed hours of the test the vessel pressure was above the contractual maximum for 82 hours. Those 82 hours were not included as part of the required 2160 hours.

The coast period which followed the eighth simulated firing had an average temperature about 20° above the desired 30°F from the 240th to the 480th elapsed hour of the test. This was a result of the long weekend and holiday periods. The desired average temperature was approximately maintained from the 480th elapsed hour until the end of the coast period (790th elapsed hour) by daily cooling of the tank walls during day shift.

During the above coast period a review of the test was conducted with the NASA-MSC Technical Monitor. The following items were approved:

a. A system for automatic temperature control was desirable for the long coast periods.

b. The allowable pressure will be increased to 1×10^{-5} torr during those periods when the harness is being heated.

c. Because of the excessive temperature recorded on the gimbaling solenoids on the fourth simulated firing, and to prevent overheating the solenoids on the ninth and tenth simulated firing (156 and 113 seconds in duration separated by a one hour coast period), the duty cycle is to be revised as follows:

III, E, Test Summary (cont.)

(1) Shorten the scheduled coast period between the eighth and ninth simulated firings in order to permit an extension of the coast period between the ninth and tenth simulated firings.

(2) Heat the harness to the maximum temperature following the ninth simulated firing (the maximum temperature is reached 1.5 hours after completion of the test) and immediately reduce the lamp voltage to zero.

(3) Monitor the solenoid temperature and conduct the tenth test when the solenoid temperature decays to 100°F.

(4) Conduct the scheduled heat cycle after the tenth simulated firing.

Supplemental Agreement No. 1 to Contract NAS9-4808, which increased the scope of quality control surveillance, was imposed on 10 December 1965. Aerojet and USAF (representing NASA) quality control inspectors monitored the test from that date to completion. Raw data was stamped by quality assurance personnel during testing. Figures 17 and 18 are representative of the degree of surveillance.

Simulated firing 1.2-02-DPE-009 was conducted on 13 December 1965. The redundant position switch, which actuates when the hinged portion of the gimbaling platform is in the "up" position, became intermittent on this test. The primary switch for this position had become intermittent on the fourth test. An examination of the test data indicated that the switch was either loose on the bracket or the bracket was bending and causing intermittent operation of the switch. On all subsequent tests a quality control inspector was stationed at the viewing port to certify that the harness was being gimbaled satisfactorily. The

III, E, Test Summary (cont.)

switch operated on each cycle of gimbaling on the subsequent test, although the time increment between the time the lower switch returned to its non-actuated position and the upper switch was actuated varied from cycle to cycle. It is believed that the bracket which actuated the upper switch was bending or was loosened and caused the times to vary.

Simulated firing 1.2-02-DPE-010 was conducted on 14 December 1965. The coast period between the ninth and tenth simulated firings was lengthened per the agreement with the NASA Technical Monitor in order to prevent overheating of the gimbaling solenoids.

Simulated firing 1.2-02-DPE-011 was conducted on 15 December 1965. The temperature recording instrument failed after five hours of the heat cycle following this test with the heat cycle continuing for three hours with no temperatures recorded. The instrument was repaired and put back into service the following day.

Simulated firing 1.2-02-DPE-012 was conducted on 15 December 1965. The temperature recording instrument again failed for a three hour period during the heat cycle following this simulated firing. At this point a redundant temperature recording capability for critical parameters was established.

Simulated firings 1.2-02-DPE-013, 014, and 015 were conducted on 20 December 1965. The heat cycle for these simulated firings was continued on 21 December.

Simulated firing 1.2-02-DPE-015 was conducted on 21 December 1965. Due to an operator error only half the heat lamps were turned on for the first part of the heat cycle which followed this simulated firing. That part of

III, E, Test Summary (cont.)

the heat cycle was repeated after the last (27th) simulated firing since no heat cycle had been scheduled for that time. Following the Christmas holidays the heat cycle was continued on 27 December 1965. All heat lamps were turned on for the continuation of the heat cycle.

During the coast period which followed the sixteenth simulated firing, the automatic cooling control system was put into operation. The system uses liquid nitrogen from a storage tank to maintain a specific temperature (adjustable at the inlet to the vacuum tank outer shell). Several days of checkout were required to establish the correct balance of storage tank pressure, area of the vacuum tank exposed to the cold nitrogen, and the temperature required at the vacuum tank outer shell inlet to maintain 30°F at the harness. During the checkout of the system the harness was unintentionally cooled to temperatures below -20°F on four occasions. A minimum temperature of -70°F was experienced on 11 January 1966. The automatic cooling system operated satisfactorily from 12 January until the end of the coast period on 7 February, although during a period of rainy weather on 29 and 30 January the average temperature at the harness appeared to decrease to approximately 22°F with no controller adjustments.

Simulated firings 1.2-02-DPE-017, 018, and 019 were conducted on 7 February 1966. Several problems, all associated with the gimbaling equipment, were encountered on the seventeenth simulated firing and two attempts were made to conduct a satisfactory 140-second simulated firing. On the first attempt the gimbaling became intermittent after approximately 51 seconds and the simulated firing was terminated after 75.6 seconds. After a brief study of the

III, E, Test Summary (cont.)

gimbaling data obtained from the abbreviated attempt, it was believed that the gimbaling solenoids were deteriorating as a result of the long exposure to the vacuum. It was decided to repeat the simulated firing for the scheduled duration with gimbaling attempted, but if the gimbaling became intermittent the simulated firing would continue for the scheduled duration. The gimbaling on the second attempt at the seventeenth simulated firing (designated 017B) also became intermittent approximately 15 seconds after the start and stopped completely 103 seconds after the start. The duration of 017B was 141.0 seconds. The gimbaling problem was eventually traced to a defective timer which was replaced between simulated firings 017B and 018. The duration of the 27th simulated firing was extended from 20.1 seconds to 160.1 seconds to compensate for the gimbaling time lost. Gimbaling was satisfactory on the eighteenth and nineteenth simulated firings.

Simulated firings 1.2-02-DPE-020, 021, 022, and 023 were conducted on 8 February 1966. The heat cycle for these simulated firings was continued the following day.

Simulated firings 1.2-02-DPE-024, 025, and 026 were conducted on 10 February 1966. The heat cycle for these simulated firings was continued the following day.

The last simulated firing, 1.2-02-DPE-027, was conducted on 14 February 1966. The test duration was extended to 160.1 seconds in order to compensate for the gimbaling data that was not satisfactory on the seventeenth simulated firing. A partial heat cycle was also conducted to compensate for the first part of the heat cycle which followed the sixteenth simulated firing in

III, E, Test Summary (cont.)

which only half the heat lamps were operated. The test continued until 0840 hours on 16 February 1966 in order to verify the data obtained on all the simulated firings before the chamber seal was broken. The extension of the test duration also had the effect of increasing the total duration with the pressure "in-spec" to more than the originally scheduled 2160 hours exclusive of the 98 hour period between 356 and 454 hours during which the pressure data was lost.

2. Problems Encountered and Solutions Presented

The problems encountered during this test and their solutions are presented below:

a. Problem: Chamber pressure exceeded maximum allowable during heat cycles.

First solution: Chamber walls were cooled with LN_2 during heat cycles. This procedure was effective; however, it reduced the effectiveness of the heat lamps.

Final solution: NASA agreed to accept 10^{-5} torr as maximum allowable when harness is artificially heated.

b. Problem: Failure of primary and redundant micro switches which actuated when harness platform was in the raised position.

Solution: Required visual verification of satisfactory gimbaling by Quality Control Inspector.

c. Problem: Vacuum measurement system power supply shutdown due to failure of electronic vacuum tube.

Solution: Repaired power supply. The lost data is considered to be within contractual limits because the pressure was within limits

III, E, Test Summary (cont.)

when power failed and when it was resumed. In addition the total testing exceeded the scheduled duration by more than the duration of the lost data.

d. Problem: Temperature extremes varied more than desired during long coast periods since the chamber was cooled during day shift only.

Solution: Installed automatic temperature control system for cooling.

e. Problem: Temperature recording instrument failed on two occasions.

Solution: Repaired instrument. Made provisions for redundant recording of temperature.

f. Problem: Unsatisfactory heat cycle on sixteenth simulated firing due to failure to activate all lamps.

Solution: Repeated heat cycle after the last scheduled simulated firing. Modified test procedures to prevent recurrance.

g. Problem: Excessive gimbaling solenoid temperature on the fourth simulated firing.

Solution: The only other simulated firings which required operation of the solenoids for extended periods of time were the ninth and tenth simulated firings which were of 156 and 113 seconds duration separated by a one hour coast period. Agreement was obtained from NASA to extend this coast period to allow the solenoids to cool.

h. Problem: Intermittent gimbaling on the seventeenth simulated firing.

III, E, Test Summary (cont.)

Solution: Replace defective timer in gimbaling circuit. Extend duration of last simulated firing from 20.1 seconds to 160.1 seconds to compensate for the unsatisfactory gimbaling on simulated firing 017.

i. Problem: On simulated firings 017A, 017B, and 020 the tape recorder was inadvertently operated at 30 inches per second instead of the standard 60 inches per second. Since the equipment which reduces the tape recorded data to the vibration plotter is adjusted for a specific tape speed of 60 inches per second, the data from the tape which was run at 30 inches per second appeared lower throughout the test, although no change to the vibration exciter input was made.

Solution: Since the reduced data was within contractual limits on simulated firing 020 and since simulated firing 017 was repeated as part of firing 027, no attempt was made to revamp the equipment in order to accurately reduce the tape data that was recorded at 30 inches per second. Figure 19 is an example of the reduced data obtained with this tape speed.

j. Problem: On simulated firing 017A through 027 the automatic equalizer had a defective slide wire contact on the 1150 cps filter (band width 25 cps) which caused the vibration level at that frequency to appear lower than the actual vibration level. No replacement filter was available; consequently, the plots show a reduced amplitude at the 1150 cps frequency.

Solution: Data accepted as meeting test requirements. It should be noted that no change was made to the vibration exciter input during the test so that actual vibration level for all the simulated tests is the same. Figure 20 is an example of the reduced data obtained with this condition existing in the data reduction equipment.

III, Technical Discussion (cont.)

F. POSTTEST CHECKOUT OF HARNESS ASSEMBLY

Following their removal from the test facility the harnesses were reacceptance tested per Specification AGC-46726. There was no significant change in the electrical portions of the acceptance test requirements; however, it was noted that the outer braid (fiberglass - teflon) was frayed in several places and the knurling on two of the connectors was damaged. The frayed braid was caused by the stanchions placed on the harness support platform to simulate possible engine contact points as described in Section C and the connector damage was apparently caused by use of an improper tool for installation or removal of the harness. Photographs of the discrepancies are presented in Figures 21, 22, 23, and 24. The acceptance-test data obtained before and after the test are presented as Appendix "B".

IV. DATA ANALYSIS, CONCLUSIONS, AND RECOMMENDATIONS

There are no differences in the data from the pretest and posttest harness acceptance tests that would indicate that the long duration vacuum test caused any degradation of the harness. Some increase in dielectric strength was noted between the two acceptance tests. This can be explained by the drying effect of the exposure to the vacuum. No significant differences in insulation resistance or conductor resistance were noted between the two tests.

No abnormalties were noted in the harness monitoring circuits during the actual simulated firings.

It is concluded, based upon the results of this test, that the P/N 712173-1 and 712174-1 harness assemblies are completely adequate for a 90-day space mission.

IV, Data Analysis, Conclusions, and Recommendations (cont.)

As previously mentioned connectors P-8 and P-22, which mate with the combustion chamber thermistors, were not tested at the predicted temperature of 370°F because this temperature approached the melting point of the solder.

The SPS engine firing records have since been reviewed to determine if there have been any failures in these connectors which may have resulted from excessive temperature. The record review has not disclosed any failures. In addition, a connector used in a firing at AEDC which resulted in a chamber burn through has been sectioned and examined. The results of the examination did not disclose any discrepancies even though the outer surface was charred. It is concluded that the 370°F temperature predicted in the thermal analysis is excessive and that the 90-day test conditions are probably more representative of those which will be experienced in flight.

Since absolutely no problems were encountered with the test specimens, no recommendations for improvement can be made.

All work on Phase IV, Electrical Harness Test, was concluded with the shipment of the harnesses and log books to NASA-MSC, Attn: M. Lausten, Technical Monitor on 7 April 1966*. The harnesses were shipped in an "as is" condition in 2 cartons with a gross weight of 30 pounds on AGC Shipper No. 02348.

*Pursuant to Contract NAS9-4808 and NASA-MSC TWX BG63-AT403 dated 3-30-66.

TABLE 1

Simulated Mission Duty Cycle

Function	Firing Duration, sec		Time From Launch (hrs)	Data Reduction
	Phases I,III,IV,V	Phase II		
Launch	-	-	0	
Midcourse Correction 1	17.1*	3.0	12.5	X
2	5.6	3.0	44.7	X
3	5.6	3.0	67.9	X
Lunar Polar Orbit Injection	250.5	3.0	69.3	X
Guidance Correction	1.7	3.0	70.0	
Guidance Correction	1.7	3.0	71.0	
Guidance Correction	1.7	3.0	72.0	
Guidance Correction	1.7	3.0	73.0	
Transearth Injection 1	156.0	3.0	745.0	X
2	113.0	3.0	746.0	X
Midcourse Correction 1	5.5	3.0	763.8	X
2	1.8	3.0	811.0	X
3	1.8	3.0	836.1	
Earth Polar Orbit Injection	10.1	3.0	841.1	X
Guidance Correction	3.0	3.0	842.1	X
Guidance Correction	3.0	3.0	882.1	X
Orbit Change	140.0	3.0	1962.1	X
Guidance Correction	2.0	3.0	1963.1	
Guidance Correction	2.0	3.0	1968.1	
Orbit Change	5.6	3.0	1986.1	X
Guidance Correction	1.7	3.0	1987.1	
Guidance Correction	1.7	3.0	1988.1	
Guidance Correction	1.7	3.0	1989.1	
Orbit Change	5.6	3.0	2034.1	X
Guidance Correction	1.8	3.0	2035.1	
Guidance Correction	1.8	3.0	2036.1	
Deboost	20.1	3.0	2160.0	X

TABLE 2

Vibration Requirements

Frequency, CPS	Remarks
10 to 90	Linear increase from 0.0026 to 0.025 g^2/cps (3 decibels per octave)
90 to 250	At 0.025 g^2/cps
250 to 2000	Linear increase from 0.025 to 0.003 g^2/cps (3 decibels per octave)

Vibration Analyzer Filter Bandwidth to be 25 cps.

TABLE 3

Phase IV Test Summary

Test	Date	Firing Duration (sec) Sched	Act.	Sched(cum)	Act(cum)	Time From Launch (hrs) Sched	Act(in Spec)	Act(Tot)	Chamber Press	Temp	Harness* Temp
001	11/11/65	17.1	22.7	17.1	22.7	12.5	9.4	24.1	5.4×10^{-7}	27	45
002	11/15/65	5.6	8.7	22.7	31.4	44.7	61.3	119.8	6.4×10^{-7}	32	43
003	11/16/65	5.6	6,8	28.3	38.2	67.9	74.2	143.0	8.8×10^{-7}	54	52
004	11/16/65	250.5	253.4	278.8	291.6	69.3	75.7	145.2	2.6×10^{-7}	-44	75
005	11/16/65	1.7	3.3	280.5	294.9	70.0	76.4	145.9	3.3×10^{-7}	-66	150
006	11/16/65	1.7	3.8	282.2	298.7	71.0	77.4	146.9	7.1×10^{-7}	-55	155
007	11/16/65	1.7	3.9	283.9	302.6	72.0	78.4	147.9	6.8×10^{-7}	-50	150
008	11/16/65	1.7	3.1	285.6	305.7	73.0	79.4	148.9	7.7×10^{-7}	-50	135
009	12/13/65	156.0	160.2	441.6	465.9	745.0	710.5	792.5	6.1×10^{-7}	46	46
010	12/14/65	113.0	112.8	554.6	578.7	746.0	732.5	814.5	2.7×10^{-7}	45	45
011	12/15/65	5.5	8.2	560.1	586.9	763.8	756.8	838.8	5.0×10^{-7}	48	48
012	12/17/65	1.8	6.6	561.9	593.5	811.0	804.9	886.9	3.4×10^{-7}	40	40
013	12/20/65	1.8	4.7	563.7	598.2	836.1	877.5	959.5	2.1×10^{-7}	36	36
014	12/20/65	10.1	12.0	573.8	610.2	841.1	882.6	964.6	2.9×10^{-6}	90	140
015	12/20/65	3.0	5.4	576.8	615.6	842.1	883.6	965.6	4.4×10^{-6}	95	156
016	12/22/65	3.0	5.1	579.8	620.7	882.1	925.6	1007.6	2.4×10^{-7}	45	45
017A	2/7/66	140.0	75.6	719.8	696.3	1962.1	2052.0	2136.0	6.0×10^{-7}	24	30
017B	2/7/66	-	141.0	-	837.3	-	2053.1	2137.1	3.0×10^{-6}	34	40
018	2/7/66	2.0	3.5	721.8	840.8	1963.1	2054.2	2138.2	1.3×10^{-5}	65	157
019	2/7/66	2.0	4.1	723.8	844.9	1968.1	2058.0	2142.0	6.0×10^{-6}	99	169
020	2/8/66	5.6	7.6	729.4	852.5	1986.1	2075.9	2159.9	9.0×10^{-7}	50	50
021	2/8/66	1.7	3.4	731.1	855.9	1987.1	2077.0	2161.0	1.5×10^{-6}	73	164
022	2/8/66	1.7	4.6	732.8	860.5	1988.1	2078.3	2162.3	2.2×10^{-6}	92	188
023	2/8/66	1.7	4.0	734.5	864.5	1989.1	2079.4	2163.4	2.3×10^{-6}	100	187
024	2/10/66	5.6	6.8	740.1	871.3	2034.1	2124.9	2208.9	1.0×10^{-6}	55	55
025	2/10/66	1.8	3.0	741.9	874.3	2035.1	2125.9	2209.9	1.5×10^{-6}	76	128
026	2/10/66	1.8	3.7	743.7	878.0	2036.1	2127.1	2211.1	1.6×10^{-6}	92	169
027	2/14/66	20.1	161.0	763.8	1039.0	2160.0	2219.5	2303.5	7.6×10^{-7}	50	50
END	2/16/66						2266.7	2350.7			

*TC-2

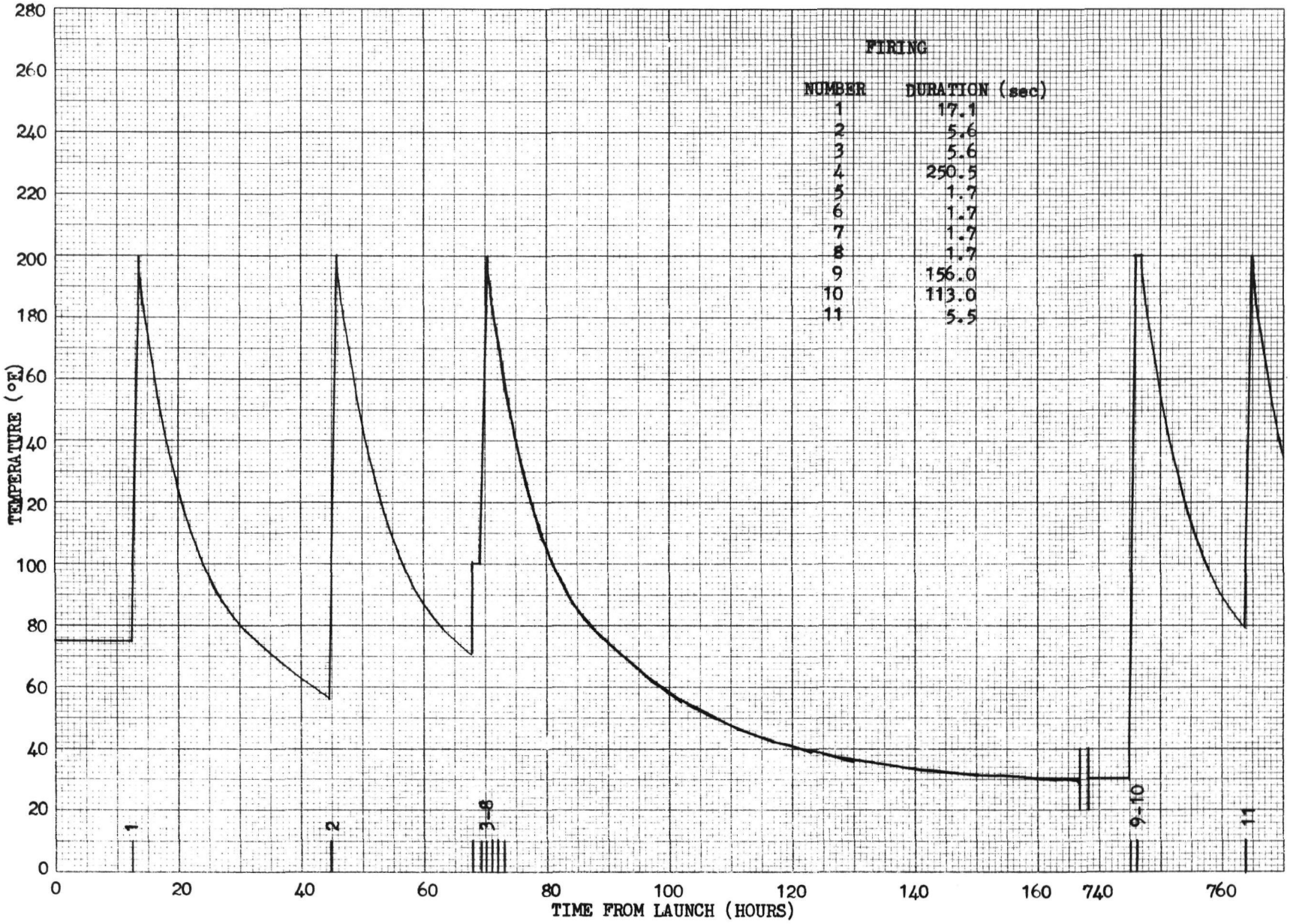


Figure 1, Target Temperature Profile

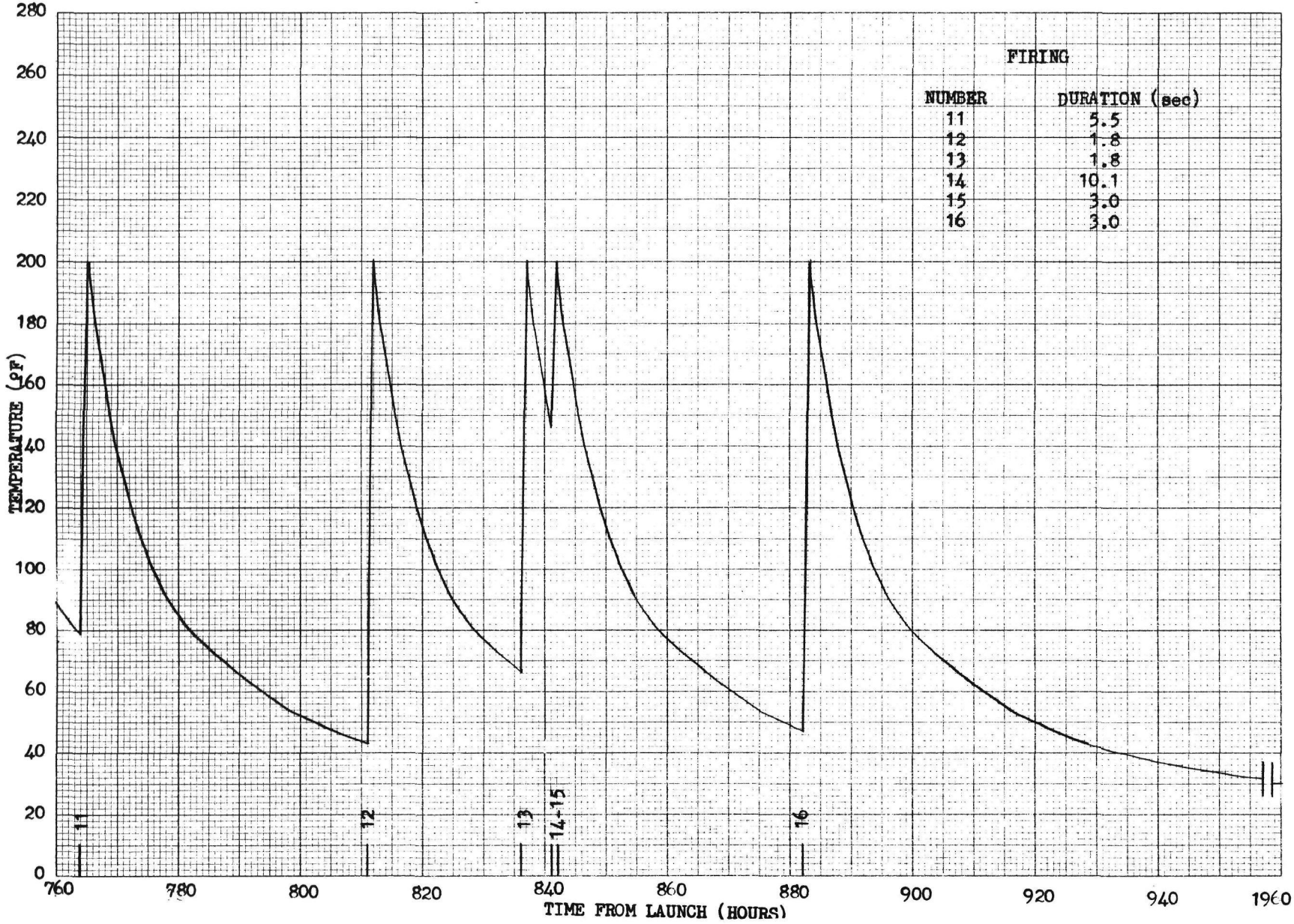


Figure 1, Target Temperature Profile (cont.)

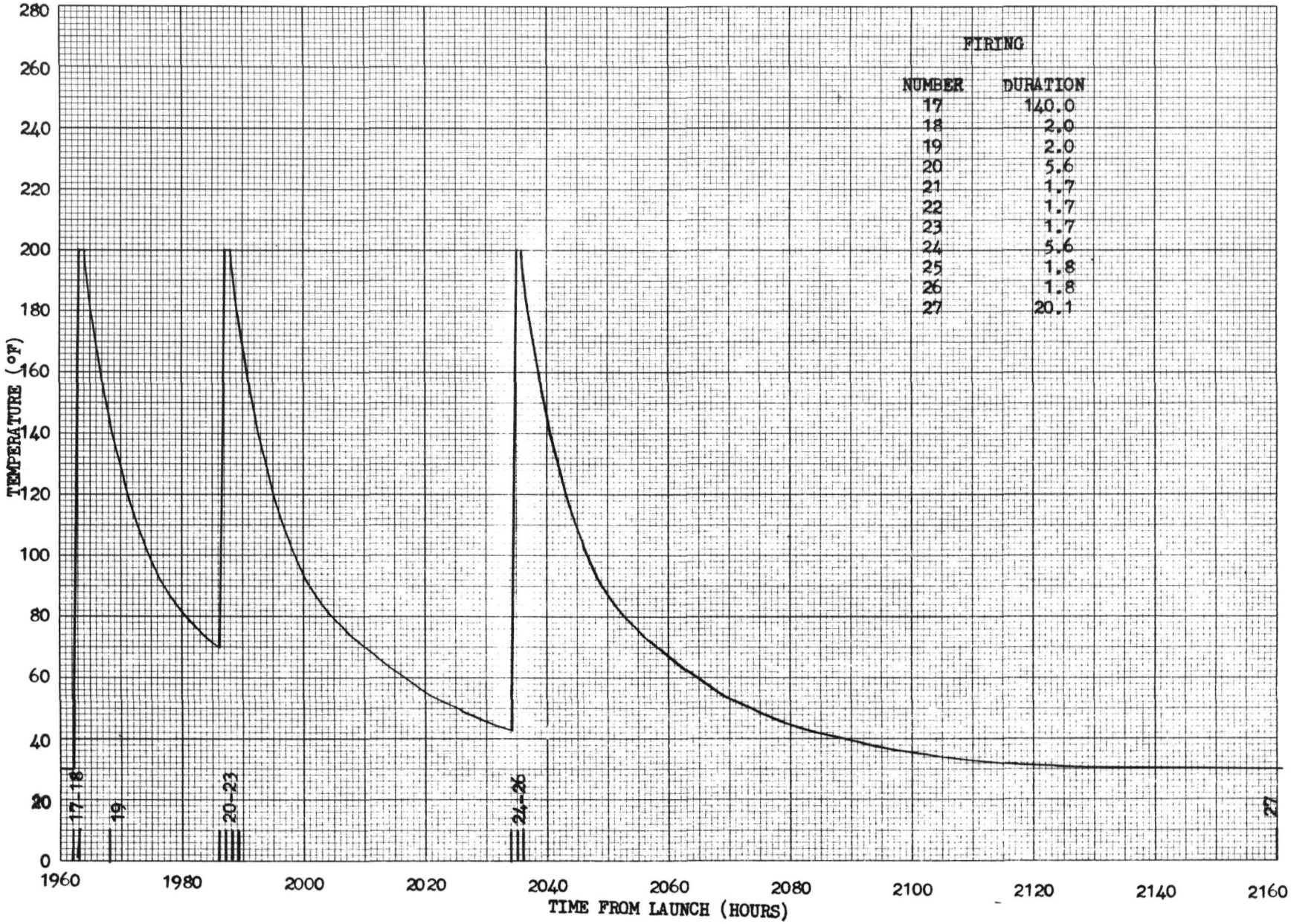


Figure 1, Target Temperature Profile (cont.)

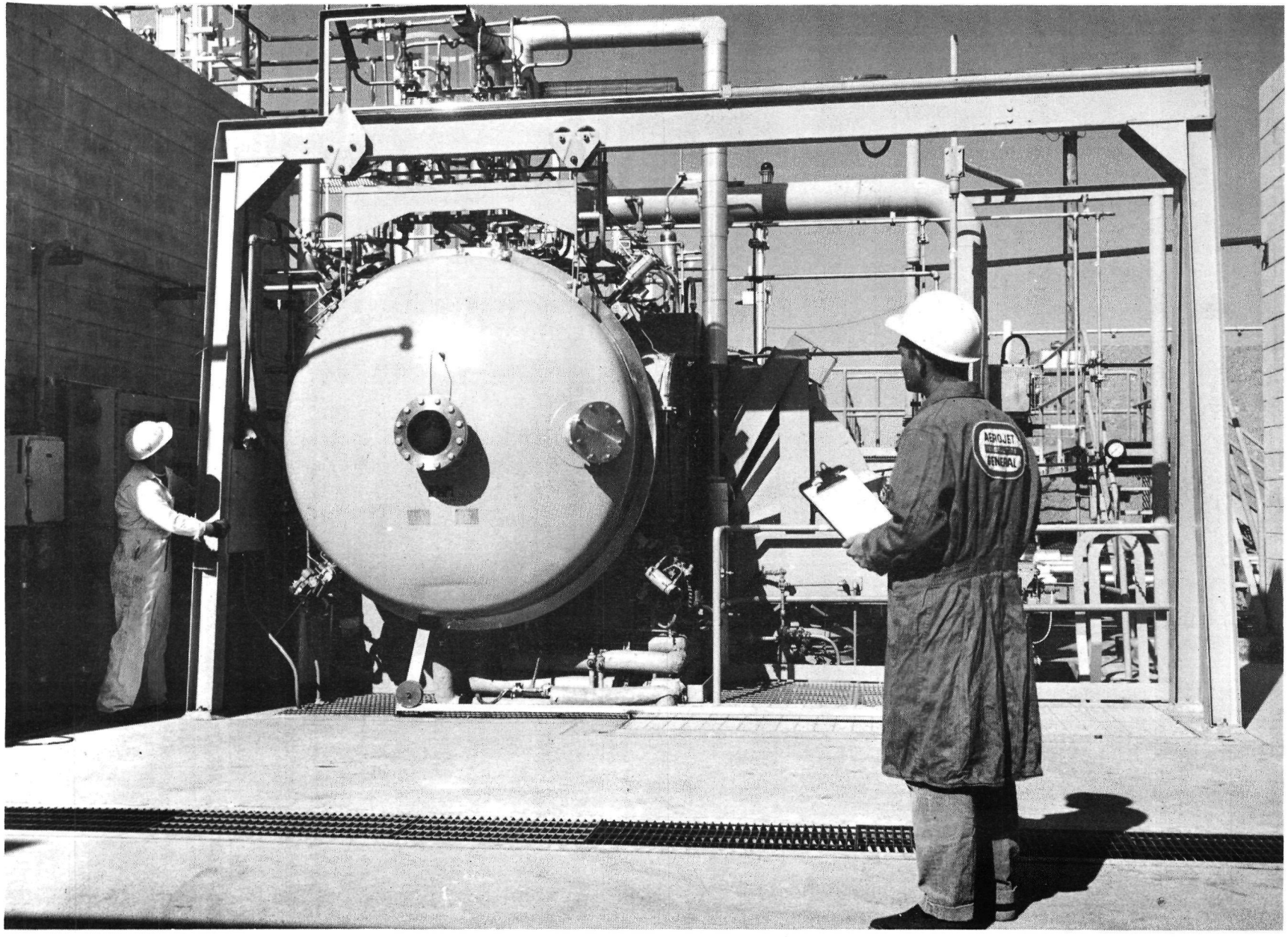


Figure 2, Vacuum Chamber and Pumping

Figure 3, Vacuum Chamber Control Console

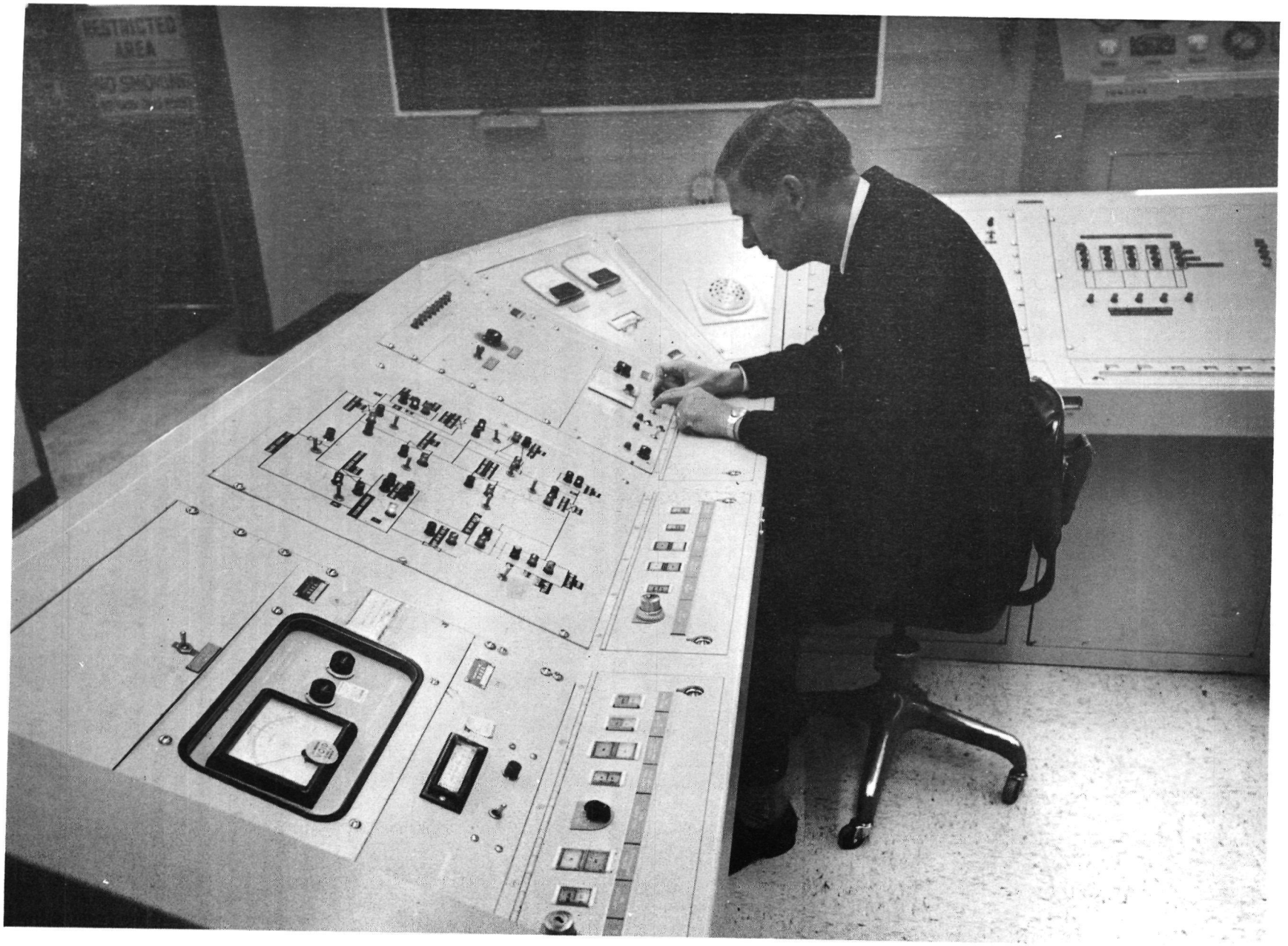


Figure 4, Main Instrumentation Panel

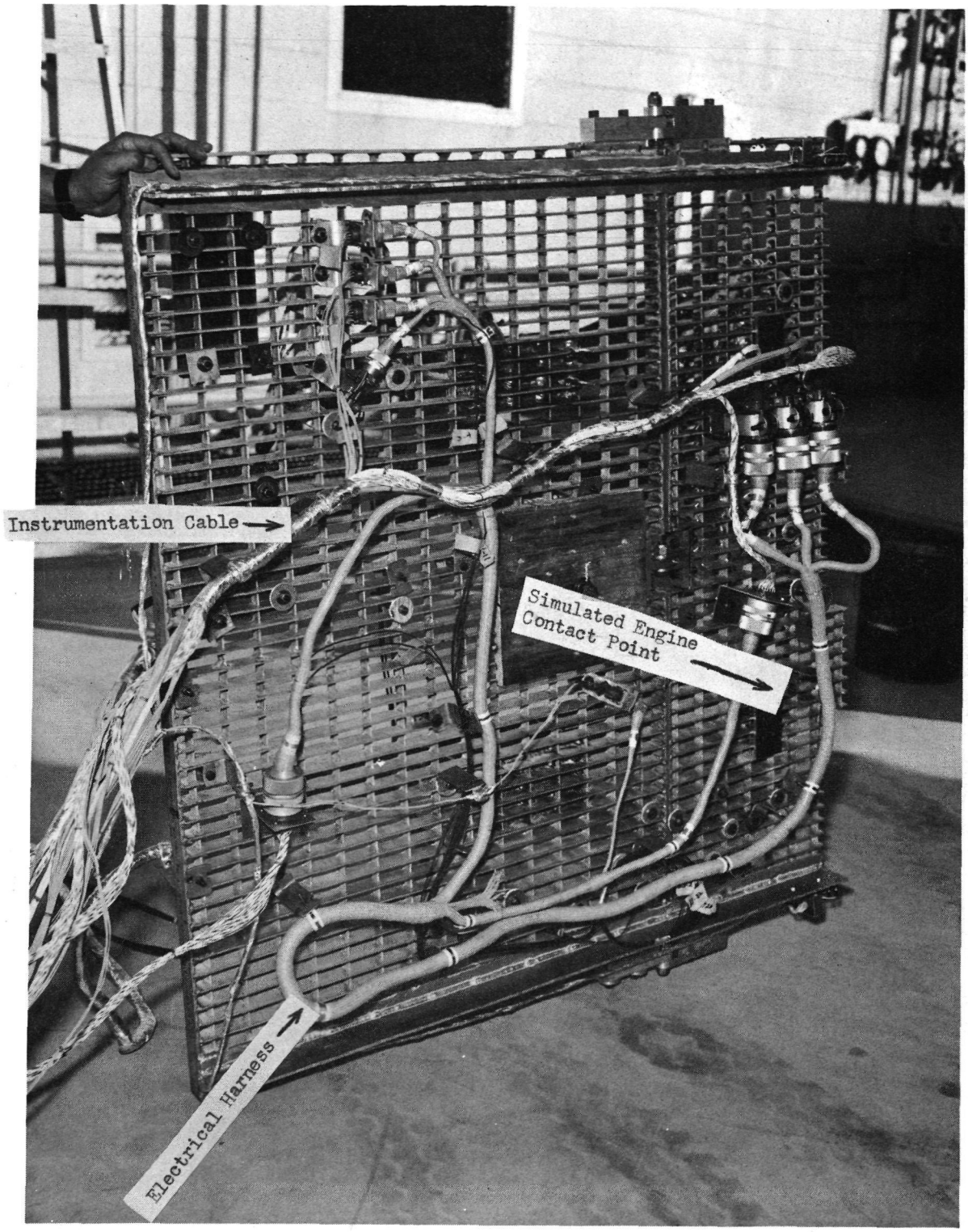


Figure 5, Harness Installation on Platform Bottom

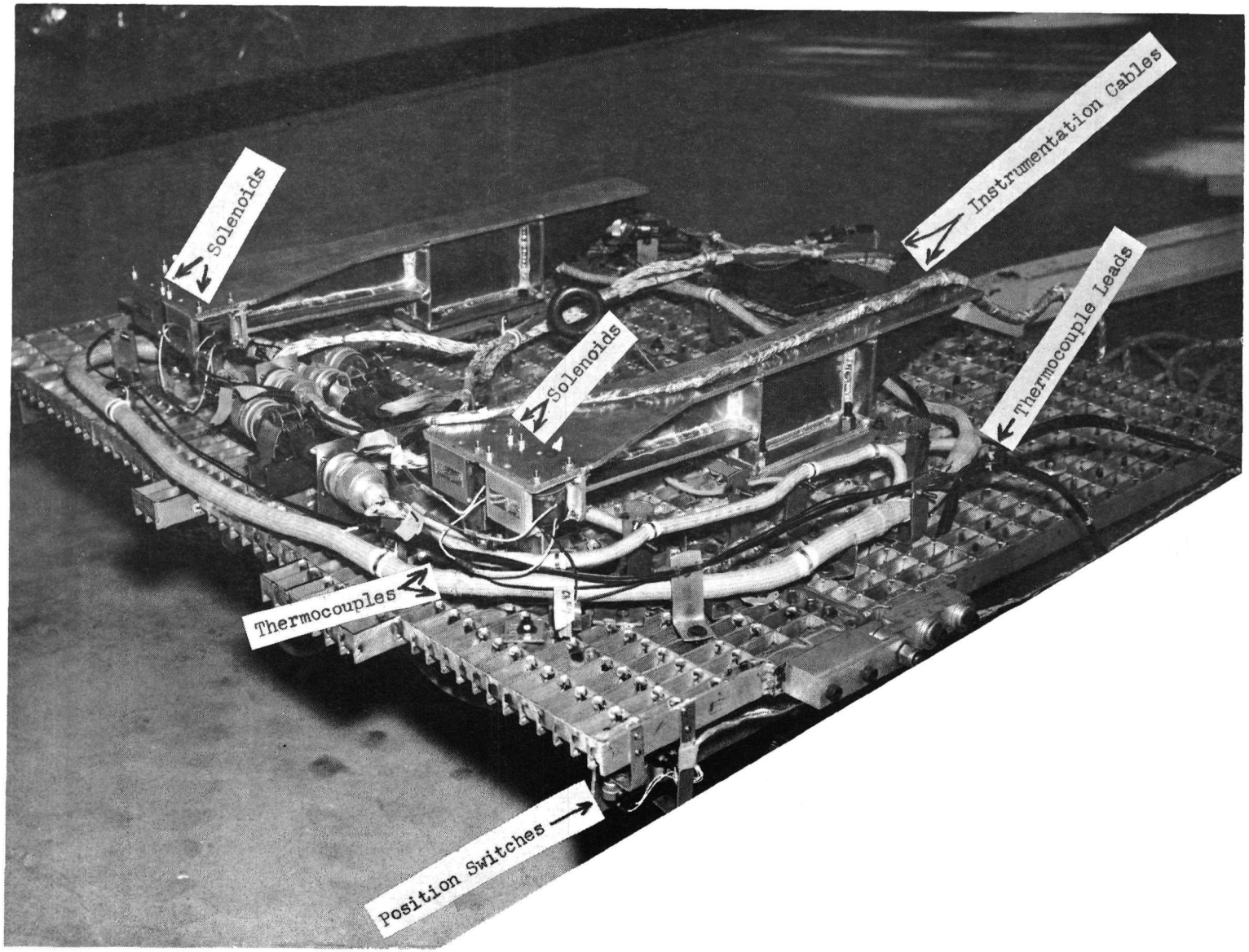


Figure 6, Harness Installation on Platform Top

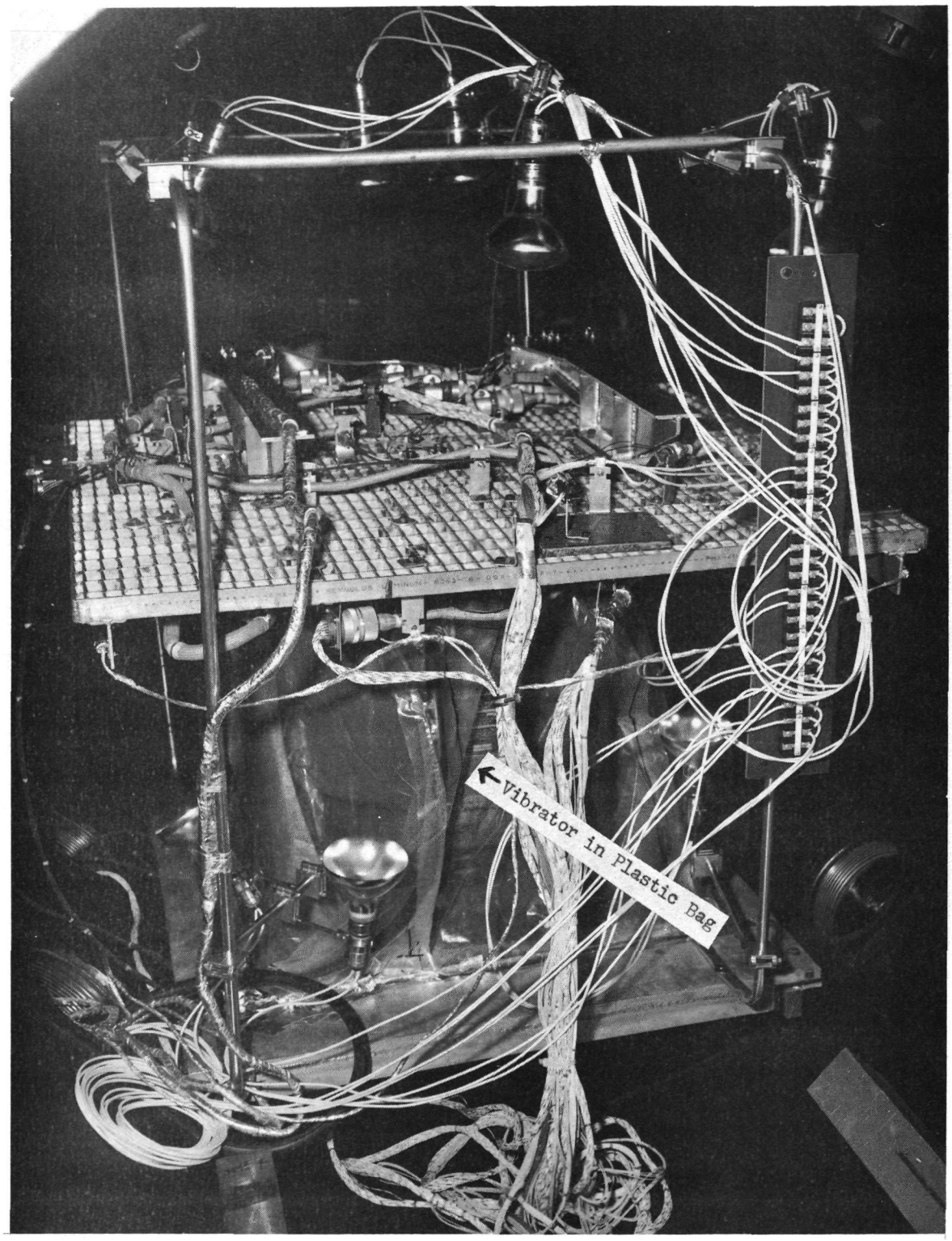


Figure 7, Test Setup in Chamber

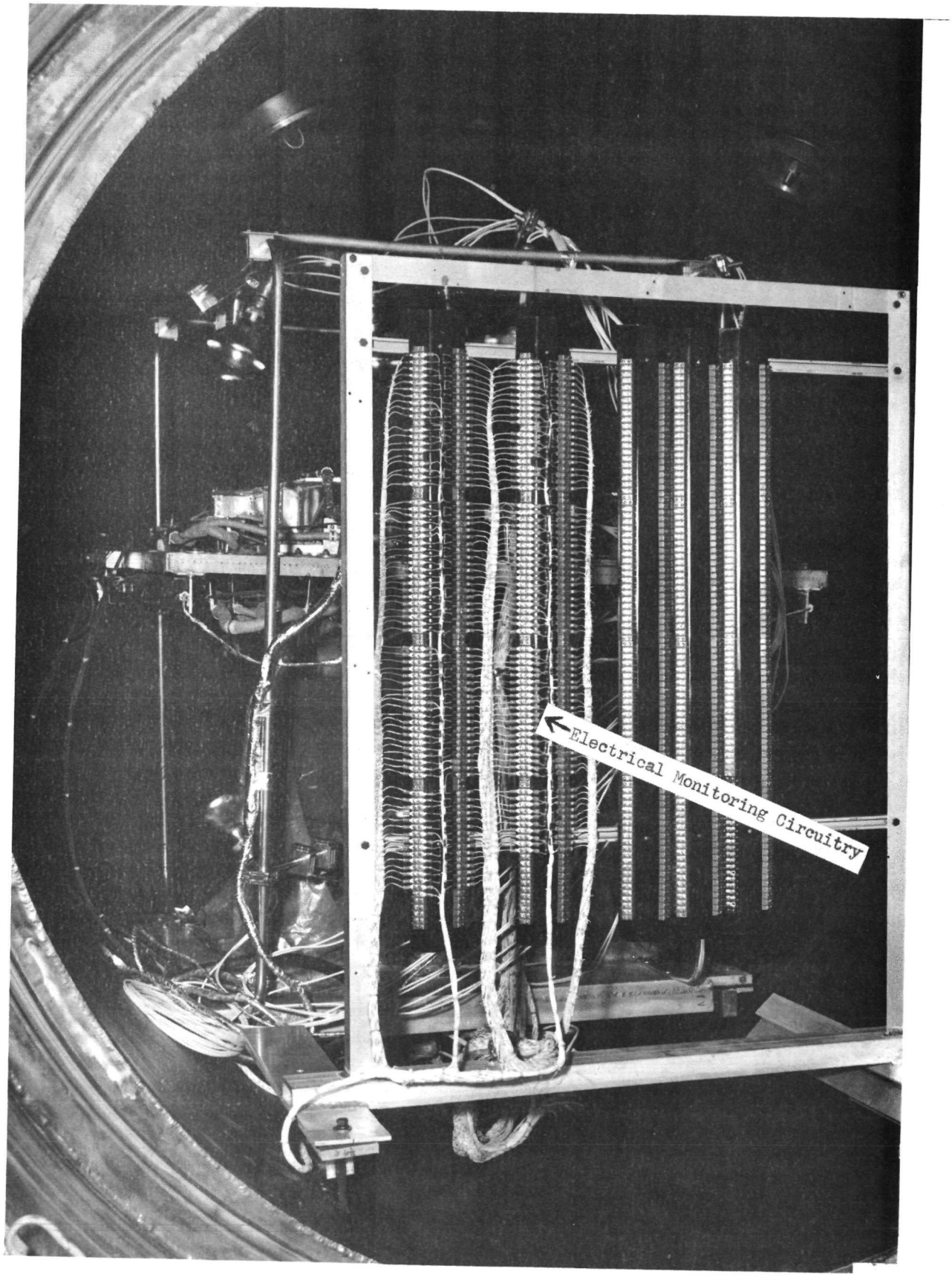


Figure 8, Test Setup in Chamber

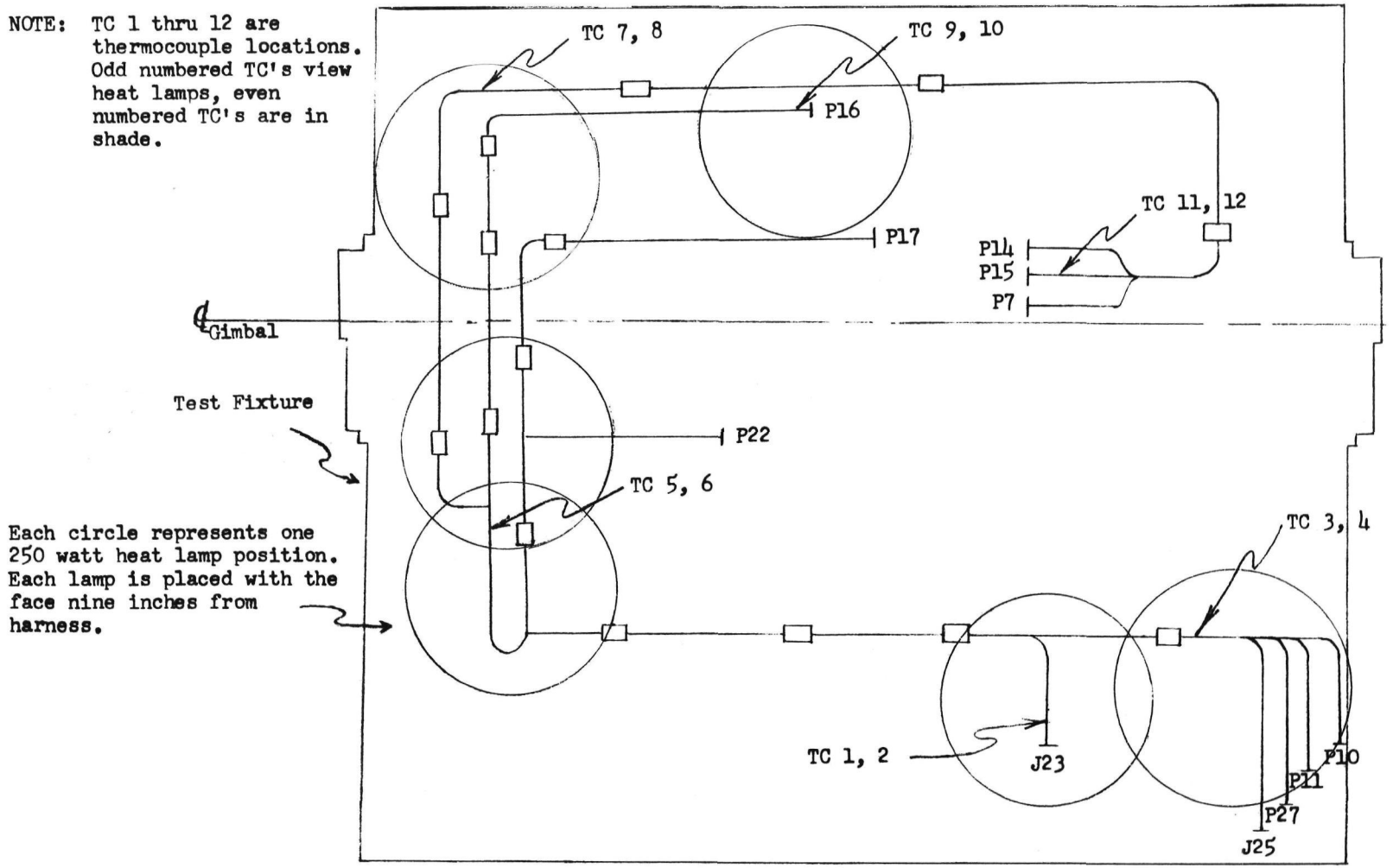


Figure 9, Thermocouple Installation, Top Harness

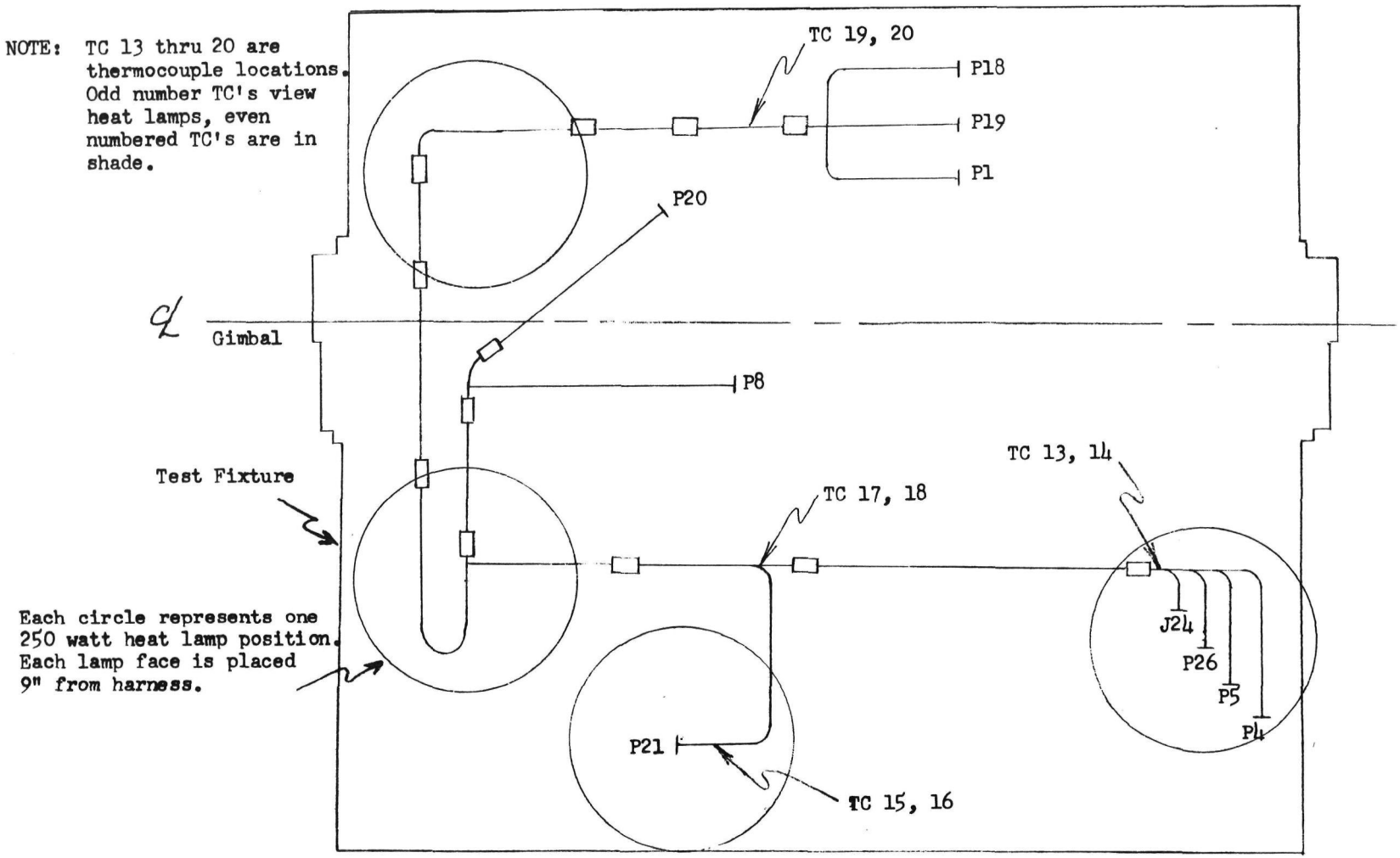


Figure 10, Thermocouple installation, Bottom Harness

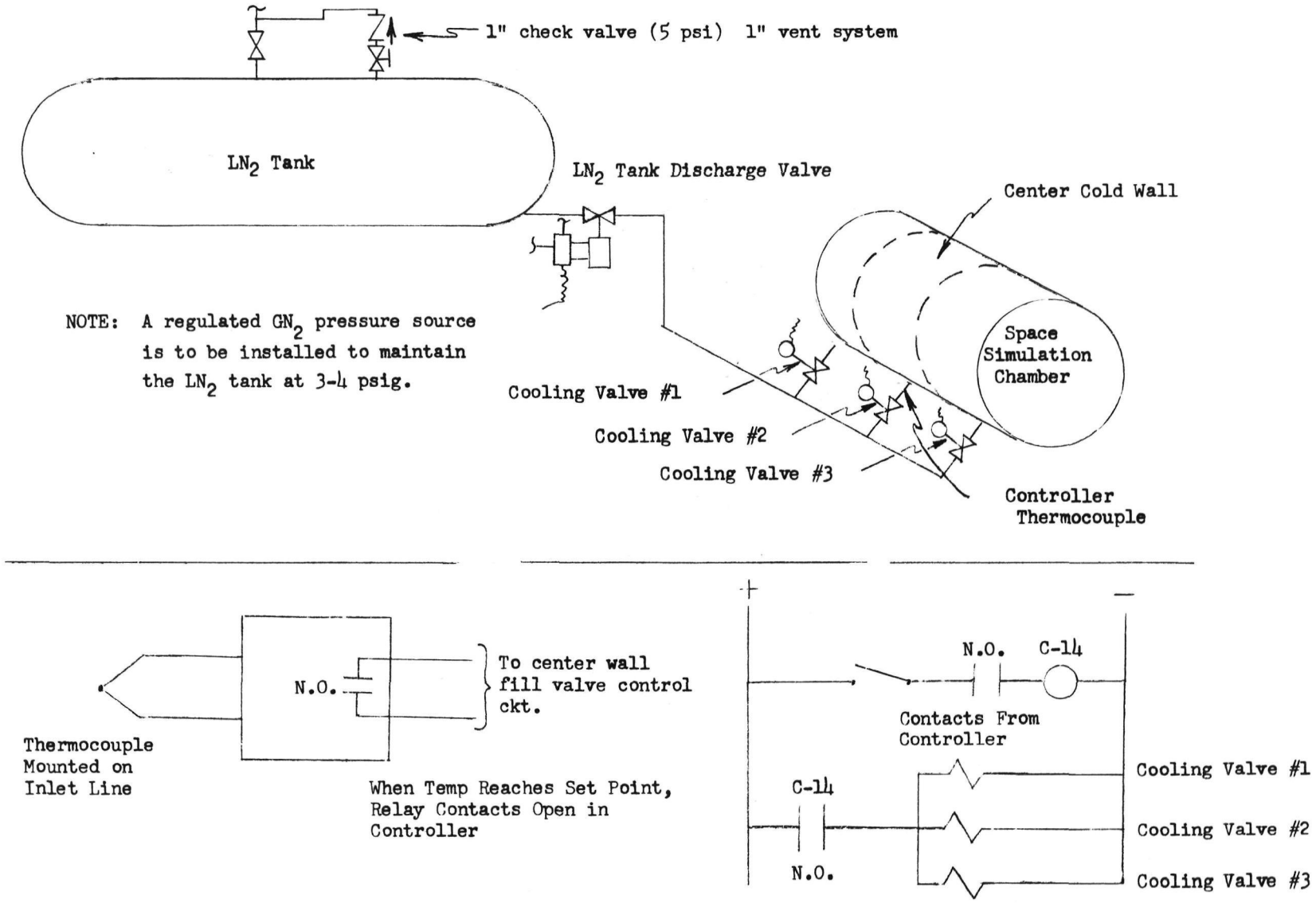


Figure 11, Automatic Temperature Control System Schematic

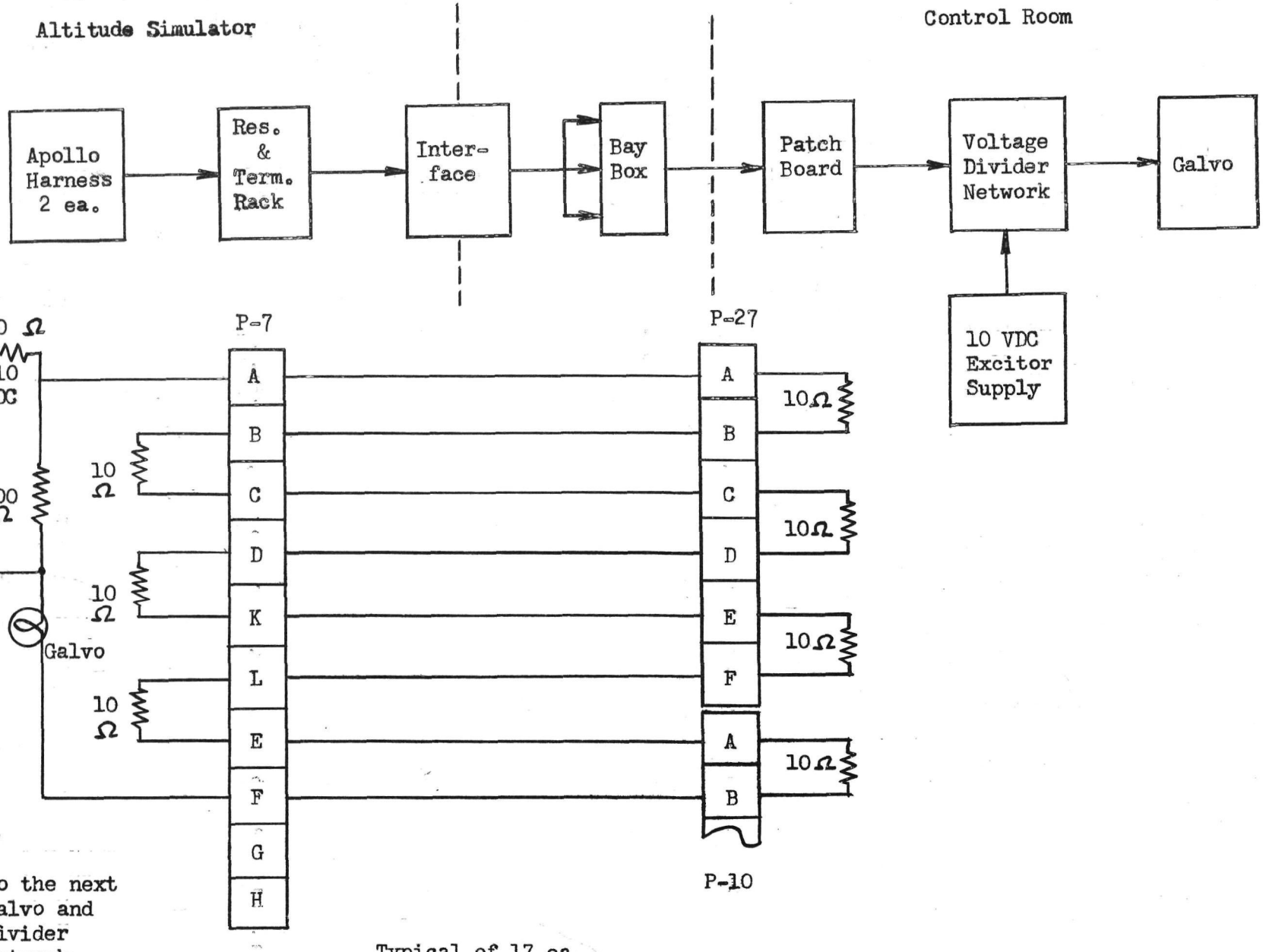
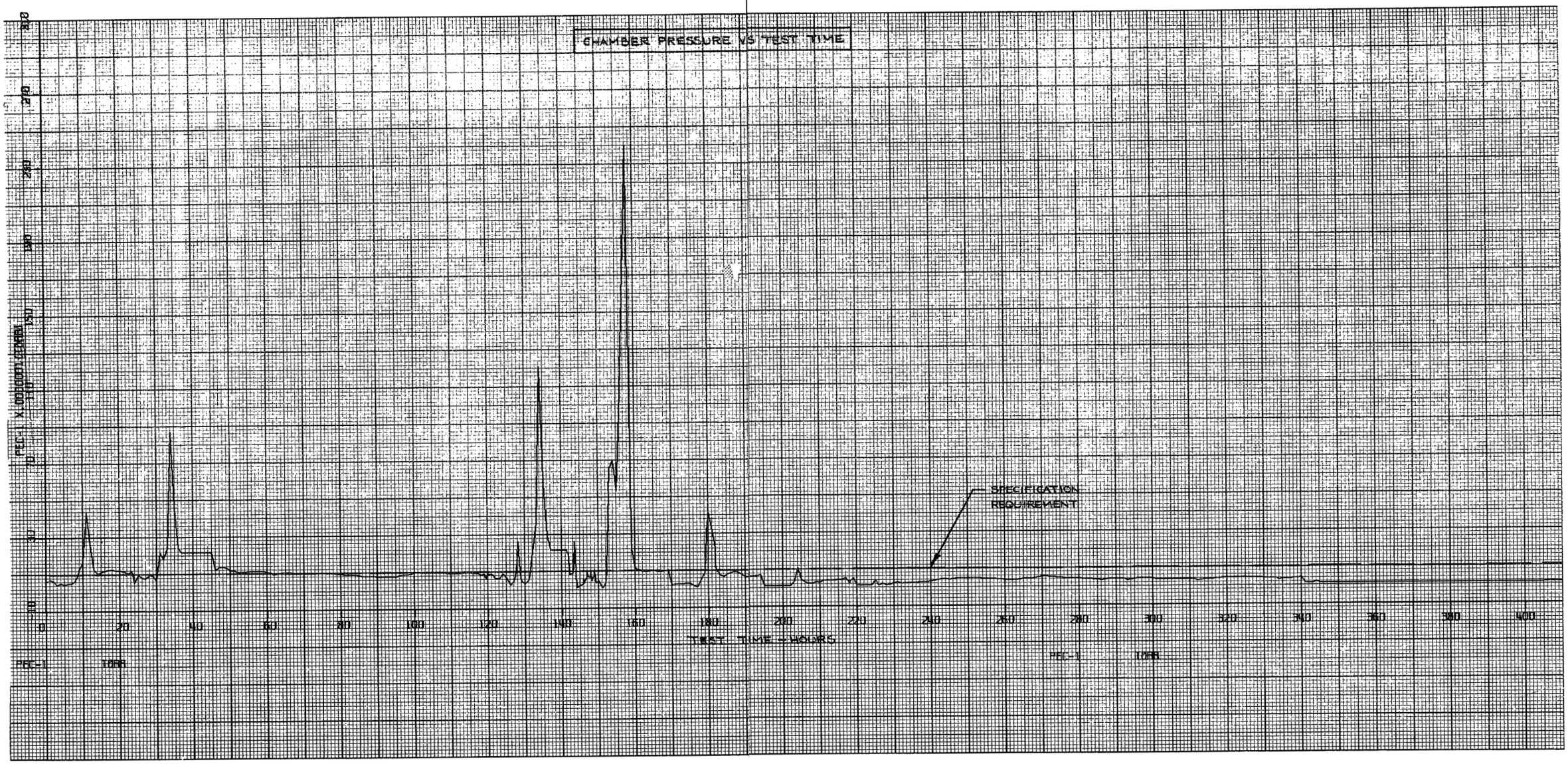


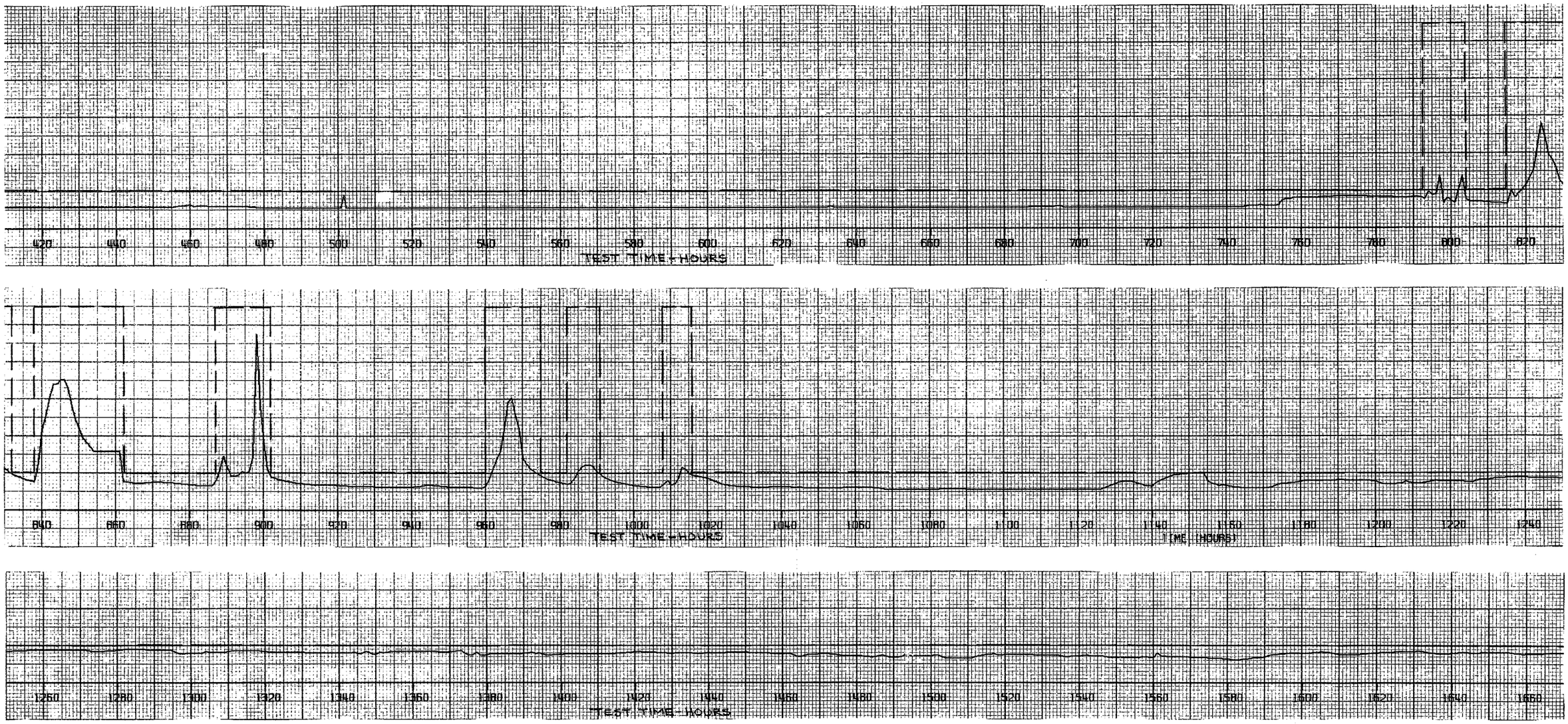
Figure 12, Harness Monitoring Circuitry



13A-1

Figure 13, Chamber Pressure vs Test Time
Page 1 of 3

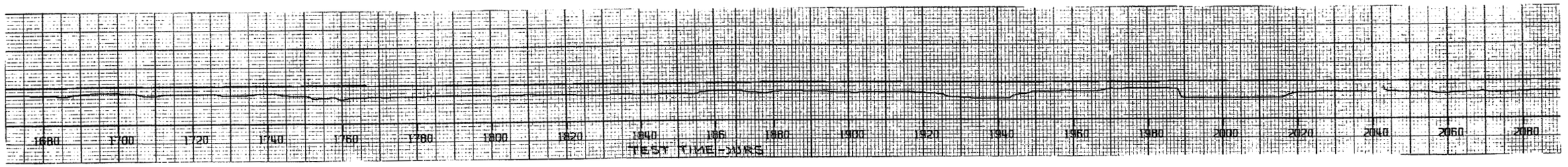
13A-2

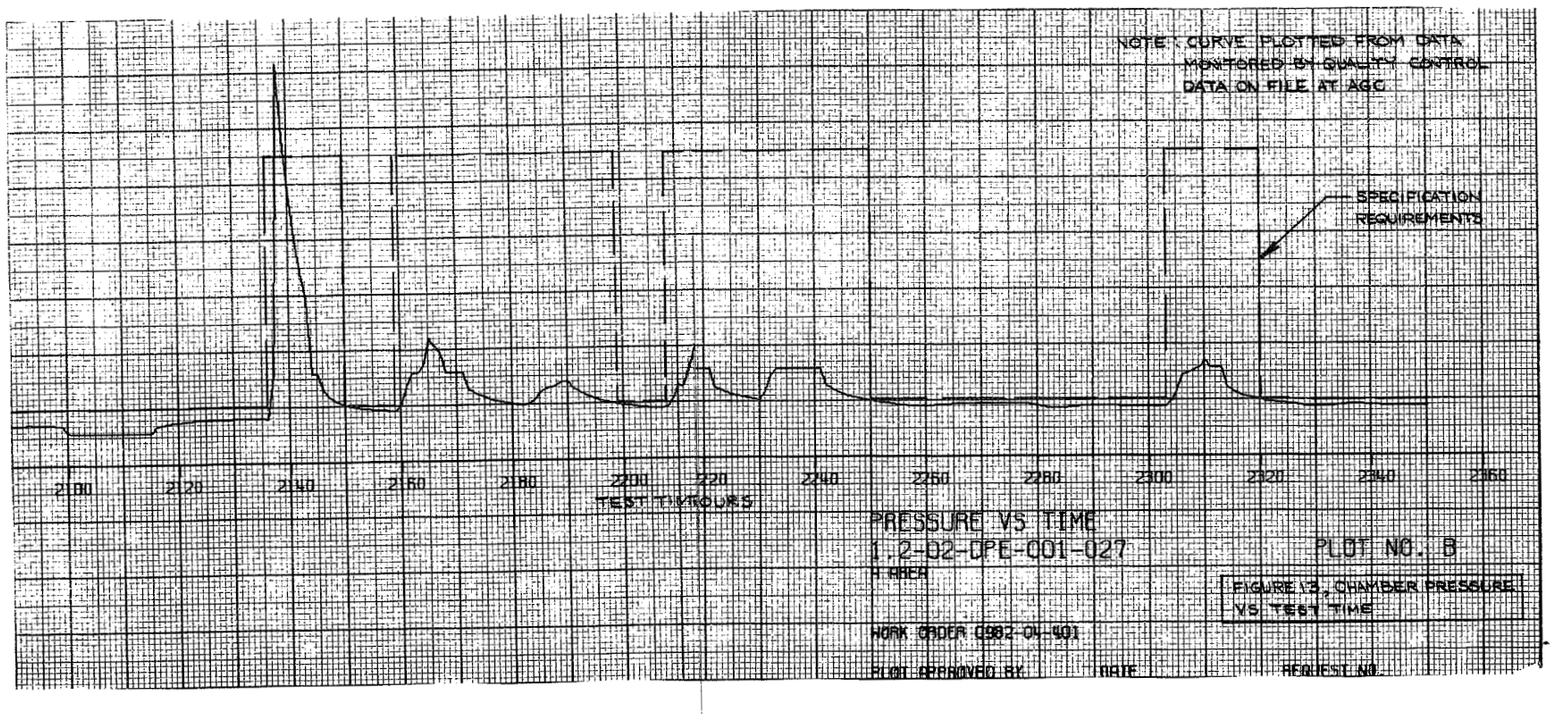


13-B-1

Figure 13, Chamber Pressure vs Test Time (cont.)
Page 2 of 3

13B-2





13-C-1

Figure 13, Chamber Pressure vs Test Time (cont.)
Page 3 of 3

13-C-2

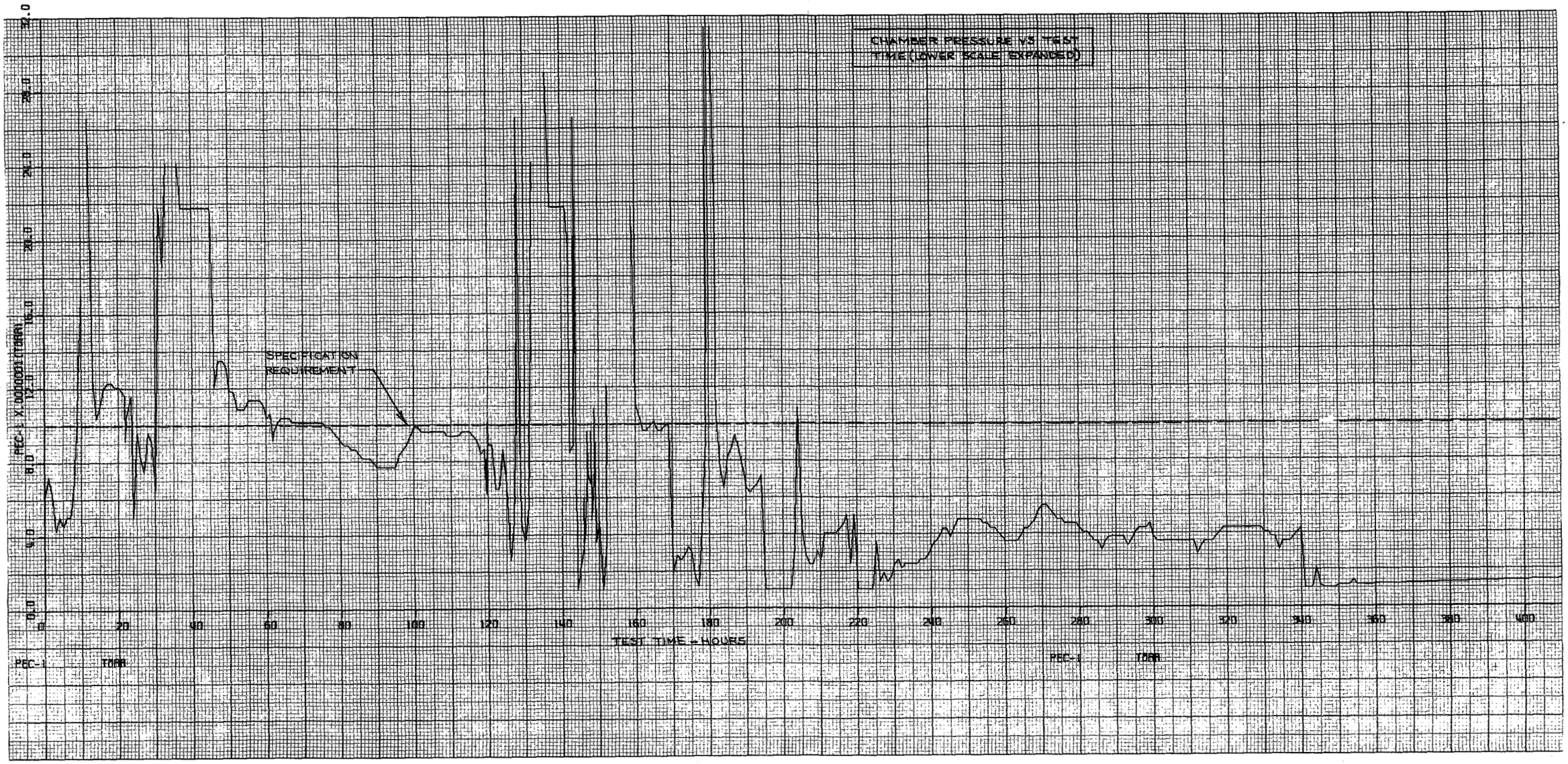


Figure 14, Chamber Pressure vs Test Time (Lower Scale Expanded)
Page 1 of 5

14-A-1

14-A-2

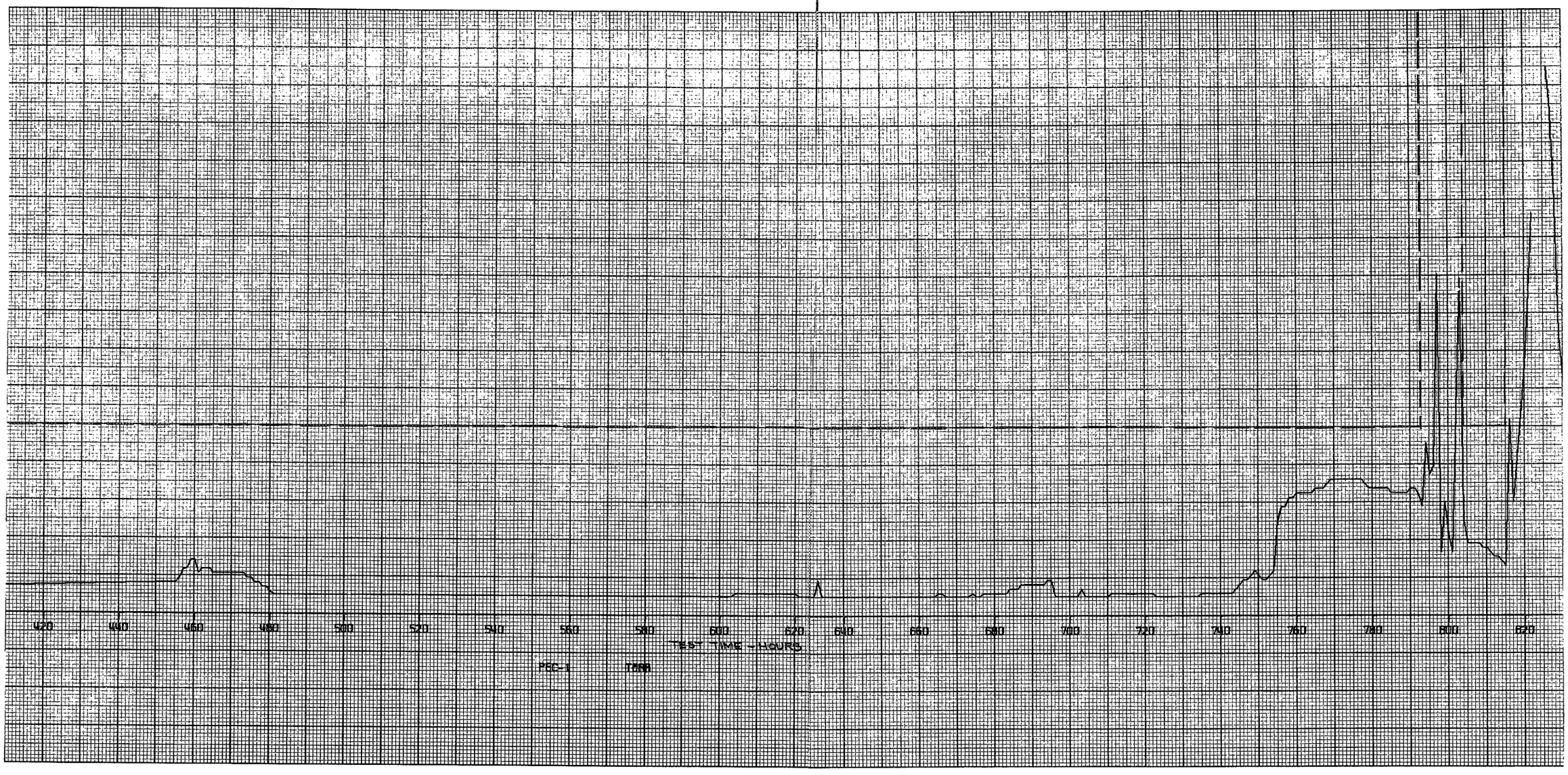
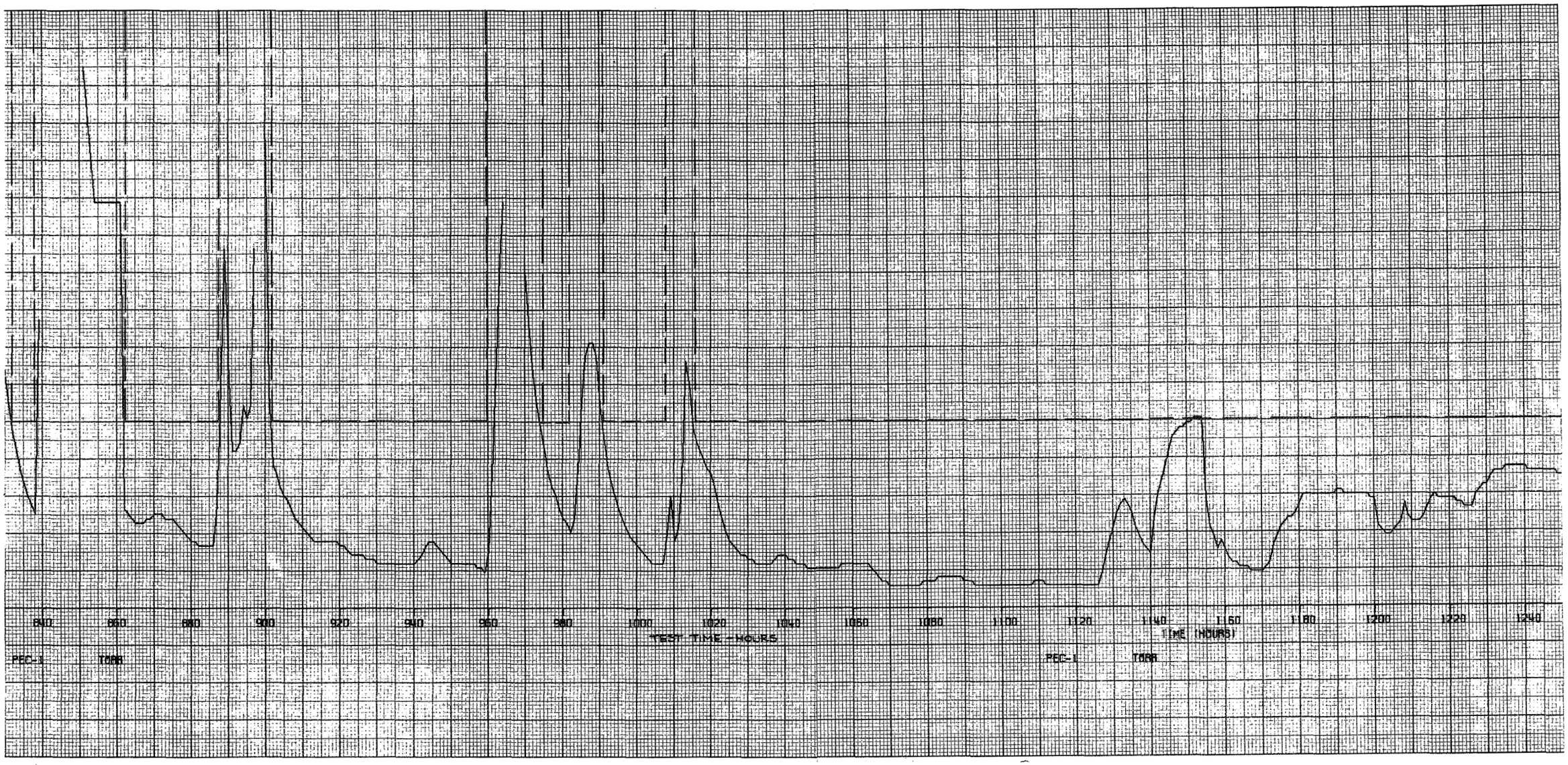


Figure 14, Chamber Pressure vs Test Time (Lower Scale Expanded) (cont.)
Page 2 of 5

14-B-1

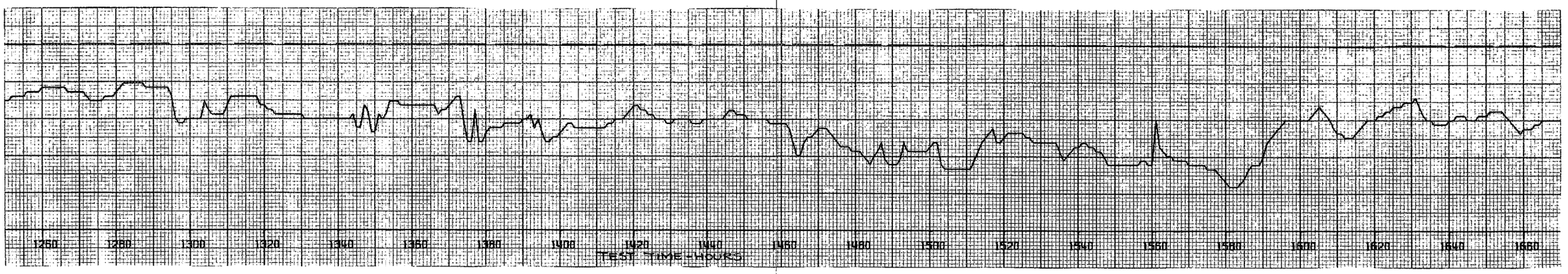
14-B-2



14-C-1

Figure 14, Chamber Pressure vs Test Time (Lower Scale Expanded) (cont.)
Page 3 of 5

14-C-2



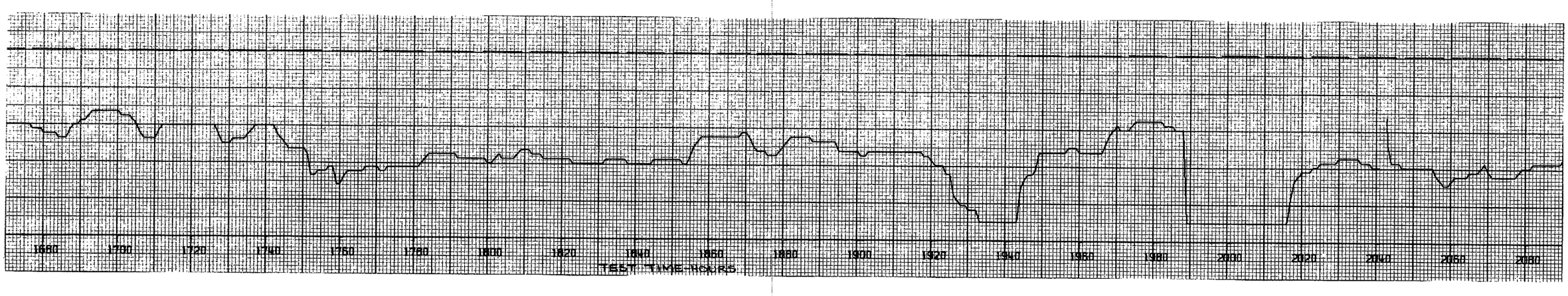


Figure 14, Chamber Pressure vs Test Time (Lower Scale Expanded) (cont.)

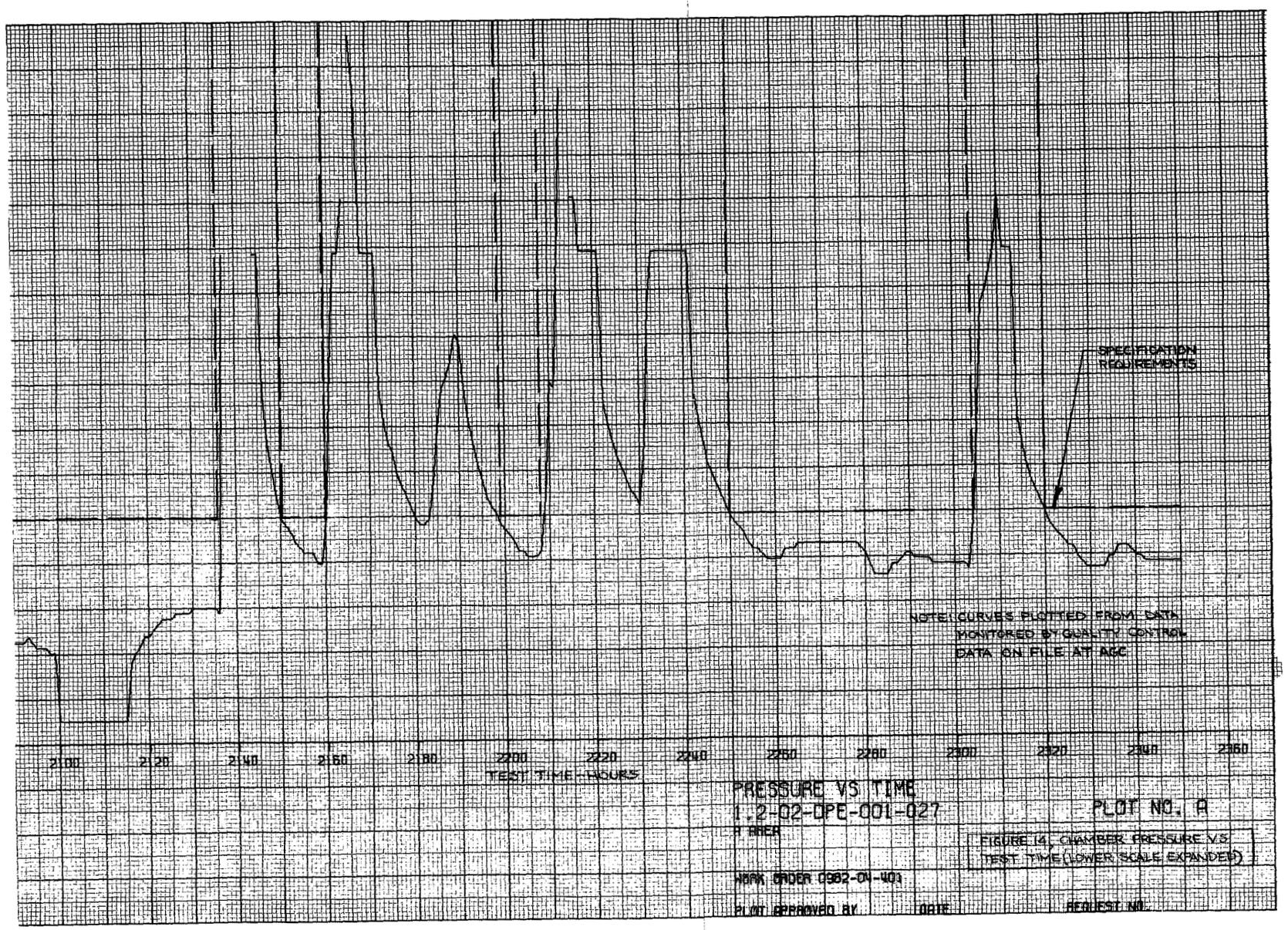


Figure 14, Chamber Pressure vs Test Time (Lower Scale Expanded) (cont.)

E-1

14-E-2

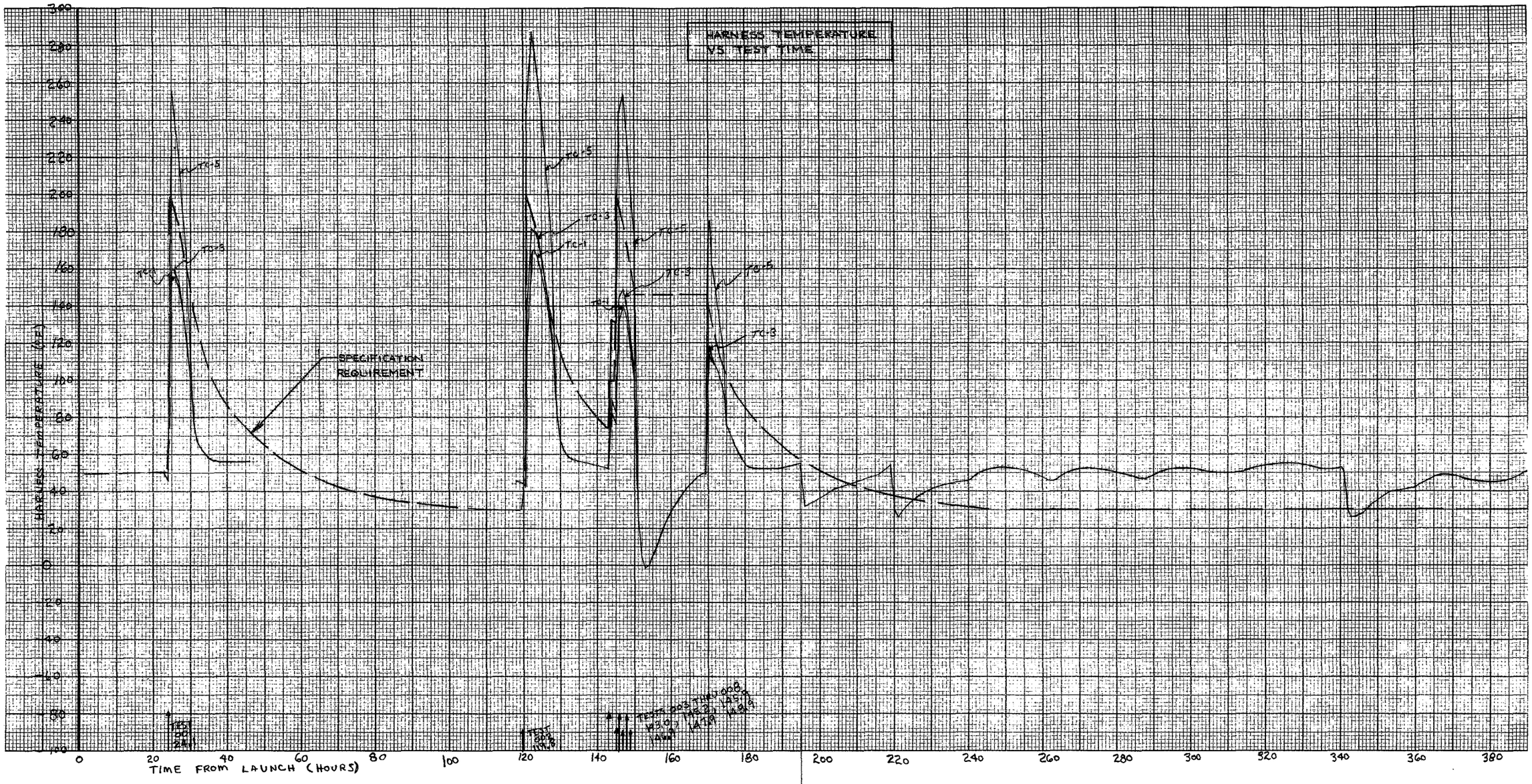
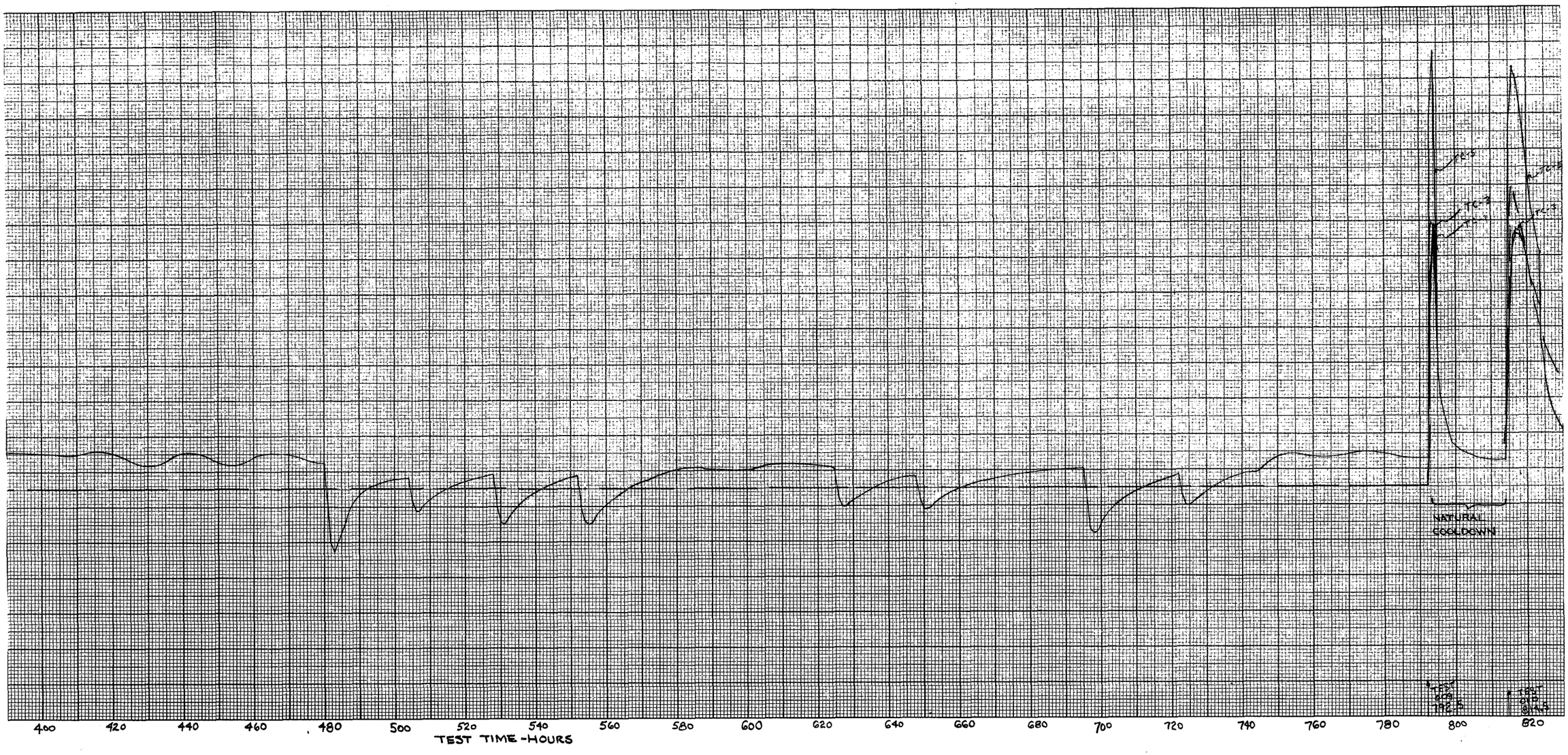


Figure 15, Harness Temperature vs Test Time
Page 1 of 5

15-A-1

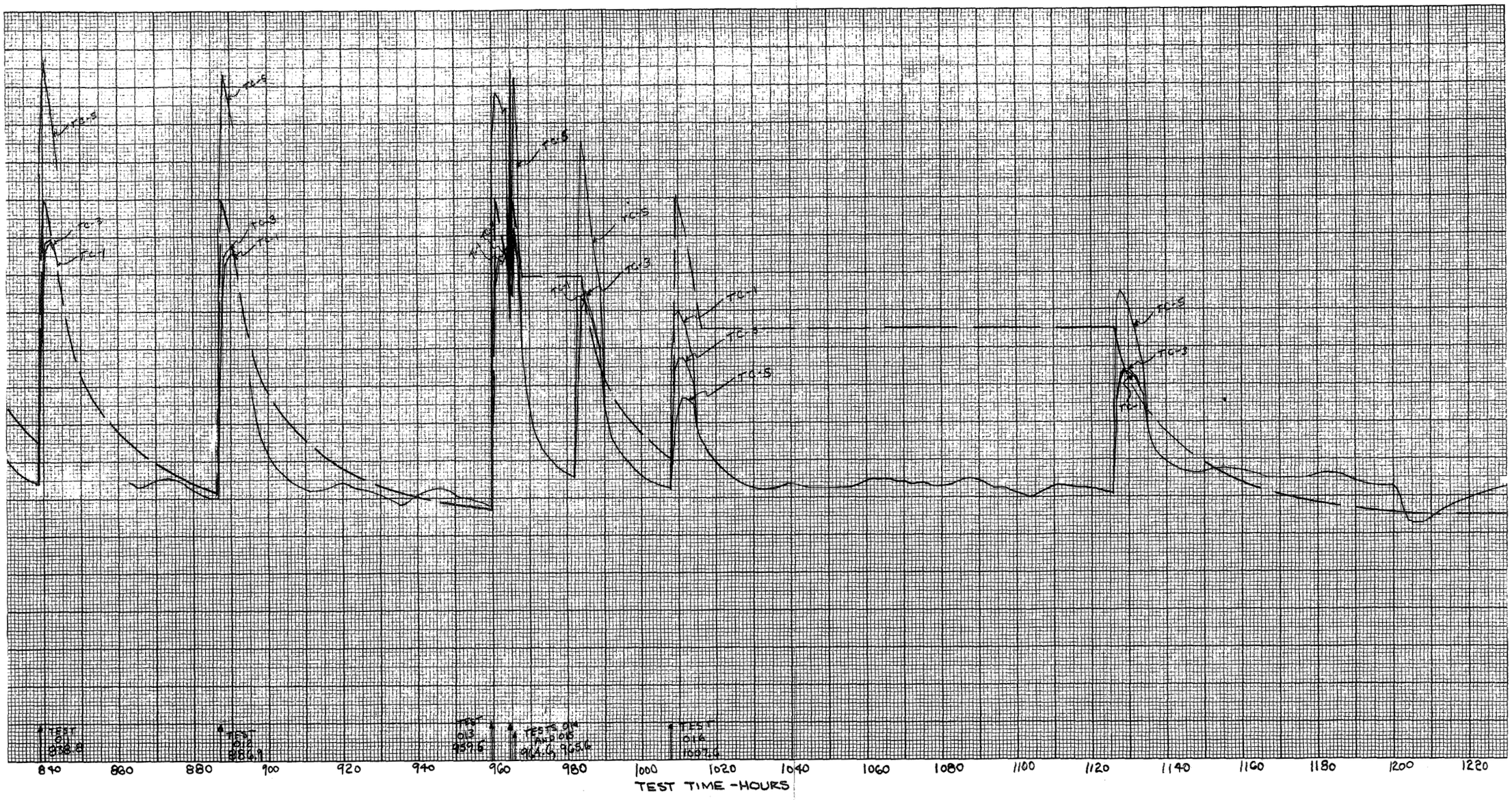
2



15-B-1

Figure 15, Harness Temperature vs Test Time (cont.)
Page 2 of 5

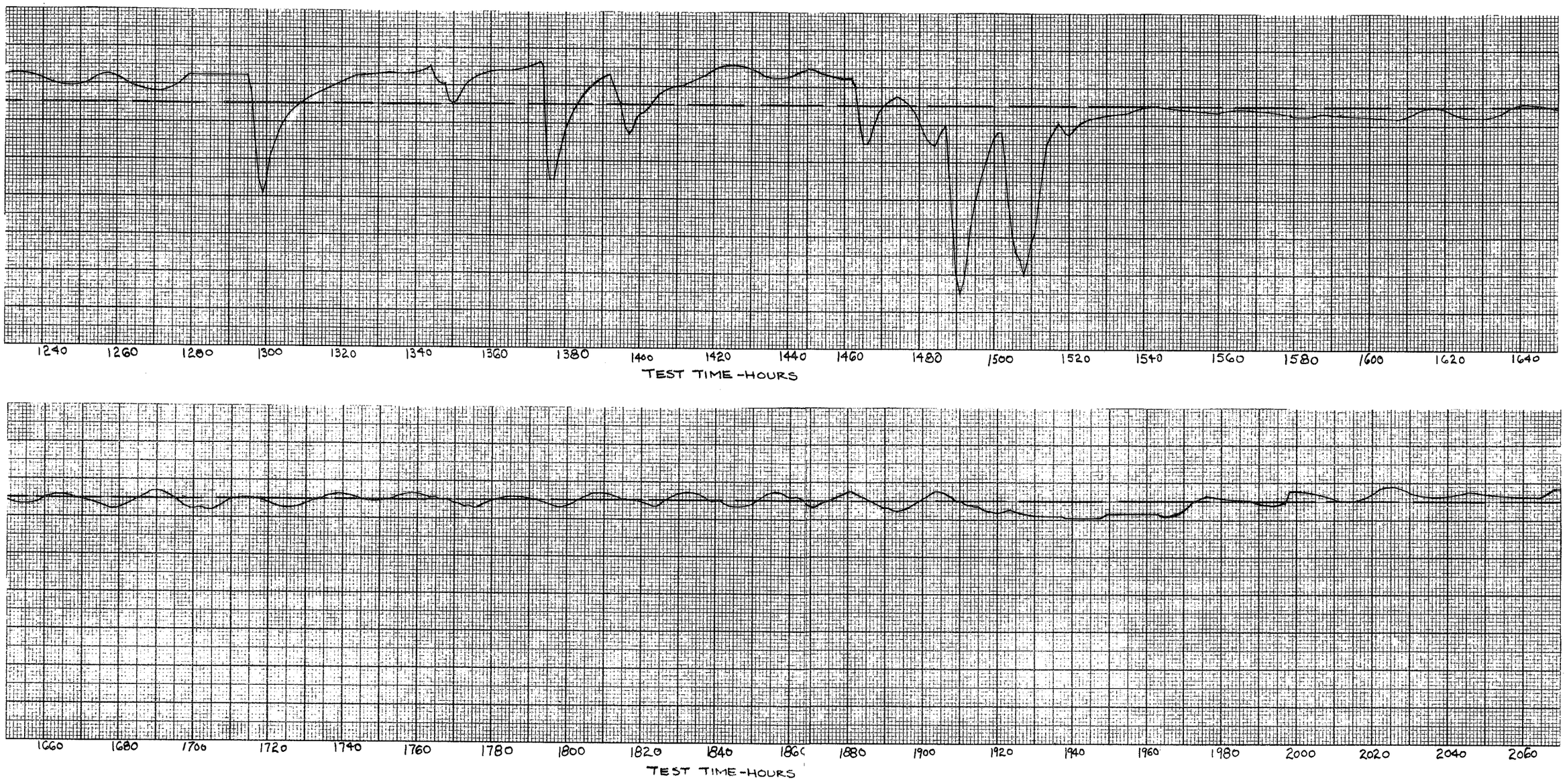
B-2



15-C 1

Figure 15, Harness Temperature vs Test Time (cont.)
Page 3 of 5

15-C-2



15-D-1

Figure 15, Harness Temperature vs Test Time (cont.)
Page 4 of 5

15-D-2

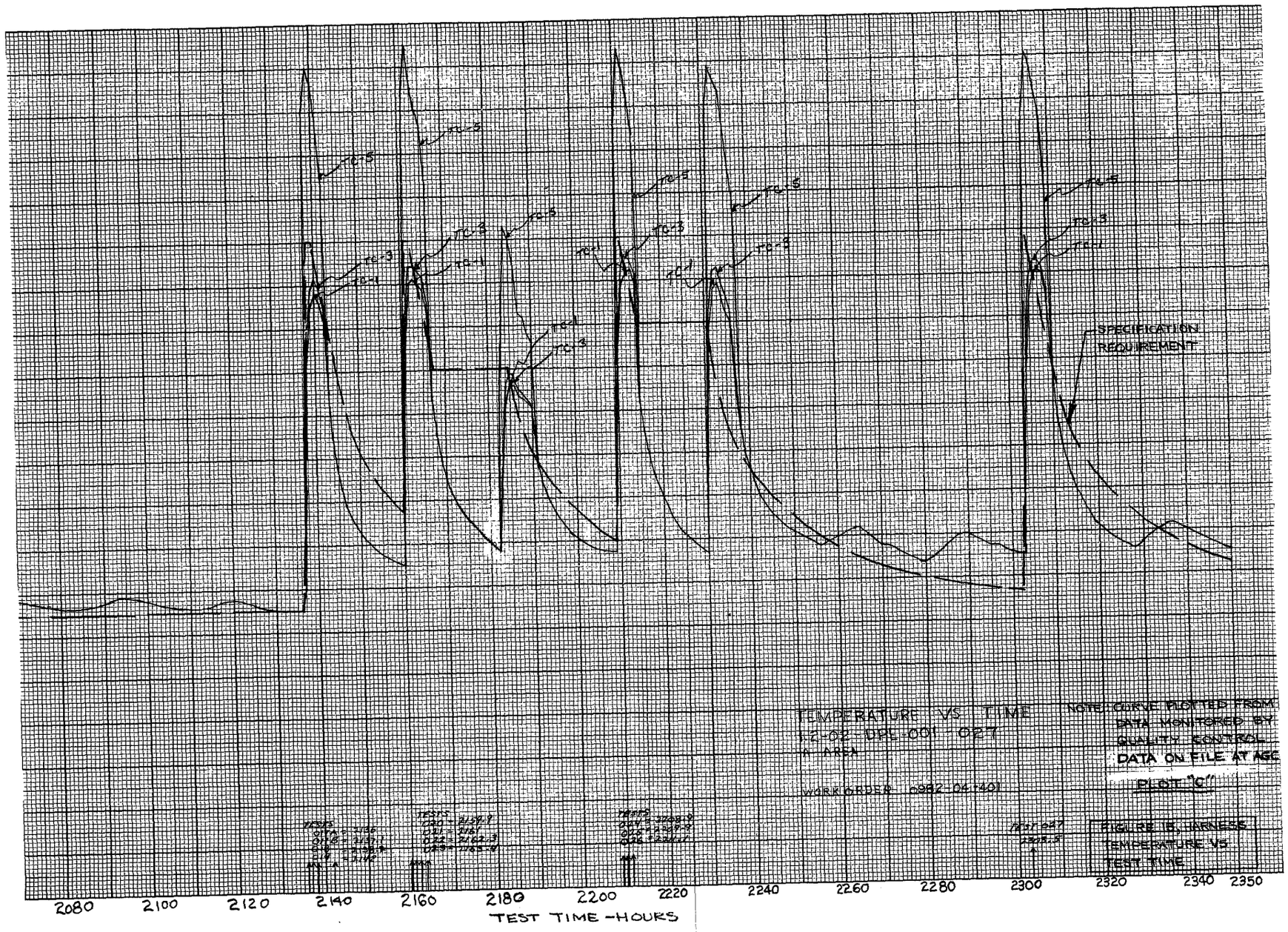
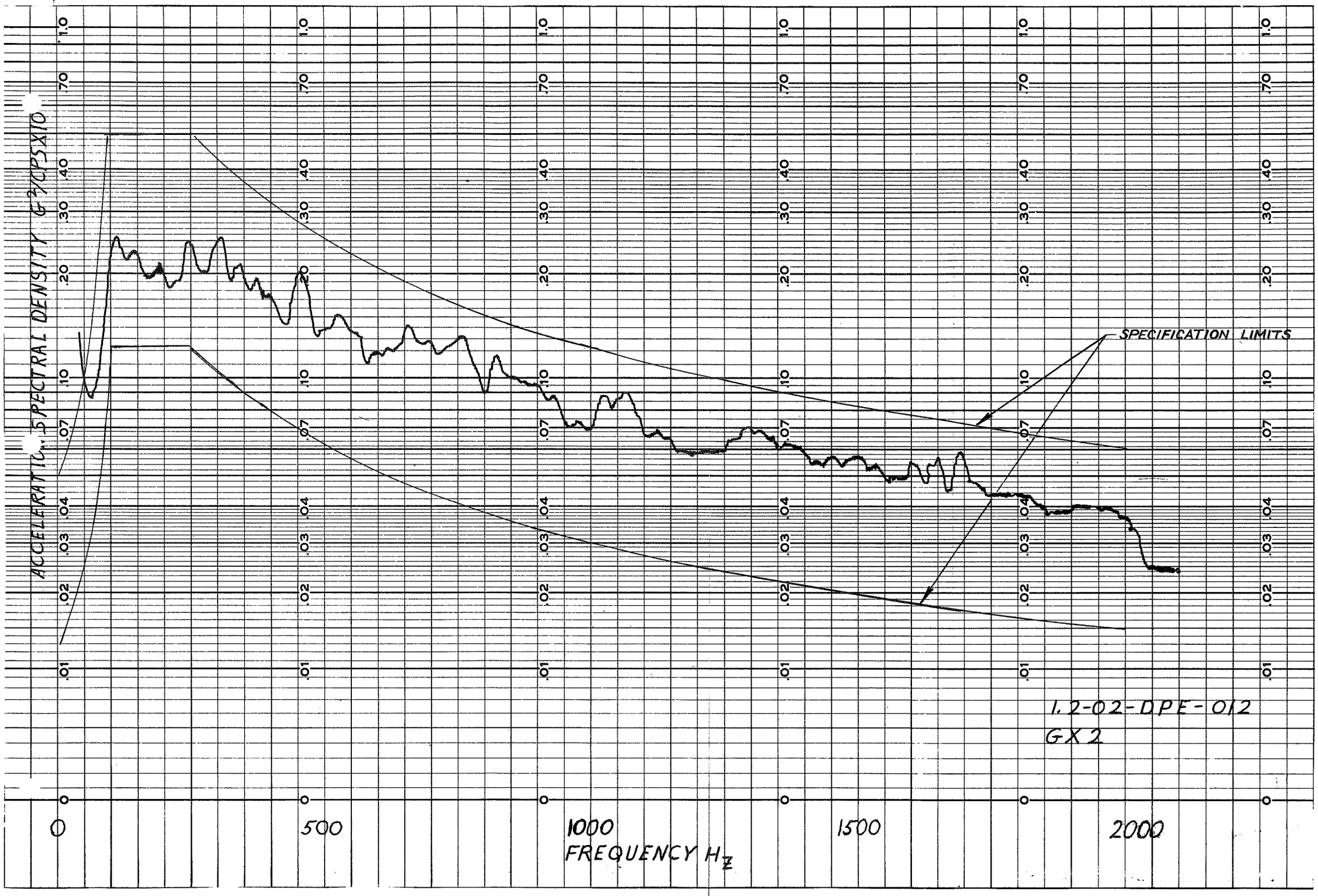


FIGURE 15, HARNESS TEMPERATURE VS TEST TIME

15-E-1

Figure 15, Harness Temperature vs Test Time (cont.)
Page 5 of 5

15-E-2



16-1

Figure 16, Typical Vibration Plot

2

AGC-4317-2 C/C87540 00030

AEROJET-GENERAL CORPORATION
LIQUID ROCKET PLANT
TEST DIVISION

PAGE 1 OF 2

ATP-TDO A-AP-2078 REV A

FACILITY A-6

TEST NO. 12-02DPE-018

UNIT S/N 34

TEST CONDUCTOR'S CHECKLIST
APOLLO X ELECTRICAL HARNESS
VIBRATION AND FLEXURE AT
ALTITUDE

PREPARED BY D. Ekstedt DATE 15 Dec 65

APPROVED R O Hunt 15 Dec 65

APPROVED — Eulenx 15 Dec 65

REFERENCE ST 3241

INITIAL T.D.	INITIAL INSP.	OPERATION
B	74 952	Index and ATP-TDO Change Letters and Revision Dates Verified.
		1.0 PRE-TEST PREPARATION:
B		1.1 Notify the following personnel a minimum of one (1) hour prior to test:
D		1.1.1 Zone Engineer
B		1.1.2 Project (Requesting) Engineer.
D		1.1.3 NAA Representative (if requested).
B		1.1.4 Q.C. Representative 0800 hours.
B		1.2 Instrumentation engineer ready.
B		1.3 Vibration Engineer ready.
B		1.4 Test engineer ready.
B		1.5 Conduct pre-test briefing session.
B		1.6 Verify space simulation chamber pressure stabilized at or below 1×10^{-6} Torr for the required time period.
		2.0 VIBRATION AND FLEXURE TEST AT ALTITUDE
B		2.1 Vibration Engineer set D.C. offset, start the shaker and notify test conductor when required run level is reached.
D		2.2 Verify Instrumentation and Vibration Engineer ready for countdown. Tape to be started on the "10" count,
D		2.3 Standby for the countdown, 10-9-8-7-6-5-4-3-2-1-START.
B		2.4 Complete required duration 2.0 seconds.
D		2.5 Standby for shutdown: "SHUTDOWN". 3-2-1 RECORDS OFF.
B		2.6 Record actual duration 2.2 seconds. Check off on data sheet.

Figure 17, Typical Checklist Depicting QC Participation
Page 1 of 2

T.D.	INSP.	OPERATION
B		3.0 HARNESS TEMPERATURE CYCLE
D		3.1 At completion of each simulated firing switch the heat lamps on. Record time lamps on 1210 hours. Checkoff on data sheet.
NA		3.2 Monitor harness thermocouples and lamp-on time, regulating per temperature profile request. Check off on data sheet.
		3.3 Switch the lamps off or reduce lamp input voltage with the variacs. Monitor temperature coastdown and adjust manually as required. Record time harness temperature reaches chamber ambient _____ hours, if applicable. Check off on data sheet.
		3.4 Conduct a low temperature cycle to 30°F. Record time harness reaches 30°F _____ hours. Check off on data sheet. (If applicable)
		3.5 Discharge LN2 from the chamber cold walls when the temperature reaches 30°F per C/L _____. (If applicable).
		4.0 POST-TEST
		4.1 Verify completion of 90 days at altitude.
D		4.2 Dive chamber to atmospheric pressure with GN2 per C/L _____.
		4.3 Remarks: Visually witnessed the movement & gimballing of specimen Feb 7, 1966
		Test Director 7/6 66@1200 Time/Date
	7A 952	Inspection and test sign-off's completed, date 2-7-66

Figure 17, Typical Checklist Depicting QC Participation (cont.)
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AGC-4-397-2 C/C87540 00390

AEROJET-GENERAL CORPORATION
LIQUID ROCKET PLANT
TEST DIVISION
APOLLO X
ELECTRICAL HARNESS
VIBRATION & FLEXURE
TESTS AT ALTITUDE

INDEX

PAGE 1 OF 1

ATP-TDO A-AP-8011 Rev. A

FACILITY A-6

TEST NO. 1.2-02 DPE-ON THRU 027

UNIT S/N

PREPARED BY L. A. Fuchs DATE 7 Feb 66

APPROVED R A Nash 7 Feb 66

APPROVED E V Knox 7 Feb 66

REFERENCE ST 3241

INITIAL T.D.	INITIAL INSP.	ATP-TDO	REVISION LTR	REVISION DATE	OPERATION
B	TA 952				DATE STARTED _____ AT _____ HOURS Index and ATP-TDO Change Letters and Revision Dates Verified.
B	QCP 4 ①	A-019	A	13 May 65	Test Hardware Receiving/Shipping Inspection
B	QCP 4 ①	AP-2081		4 Nov 65	Installation of Apollo X Electrical Harness Test Setup
B	QCP 4 ①	AP-9001		3 Nov 65	Instrumentation Pre-Test Apollo X
B	QCP 4 ①	AP-2079		3 Nov 65	Test Conductors Pre-Test Checkout, Apollo X Electrical Harness Test Setup
B	TA 952	AP-2078	A	15 Dec 65	Test Conductors Checklist Apollo X Electrical Harness Vibration & Flexture at Altitude Tests
B	TA 952	AP-2080		4 Nov 65	Apollo X Electrical Harness Vibration Test Procedure
B	QCP 4 ①	A-037		3 Nov 65	Space Simulation Chamber Test Directors Checklist Pumpdown.
B	QCP 4 ①	A-024		5 Oct 65	RTT Pre-Test Checklist Space Simulation Chamber

① These ATP's are performed once and need not be repeated on harness S/N 34's. The origional contract report to did not require QC but was added subsequent to initiation of test. QCP 4 WK 2-7-66

Test Engineer Date

All Inspection and Test sign-off's complete 2-16-66
Date

TA 952

Figure 18, Additional Example of QC Activity

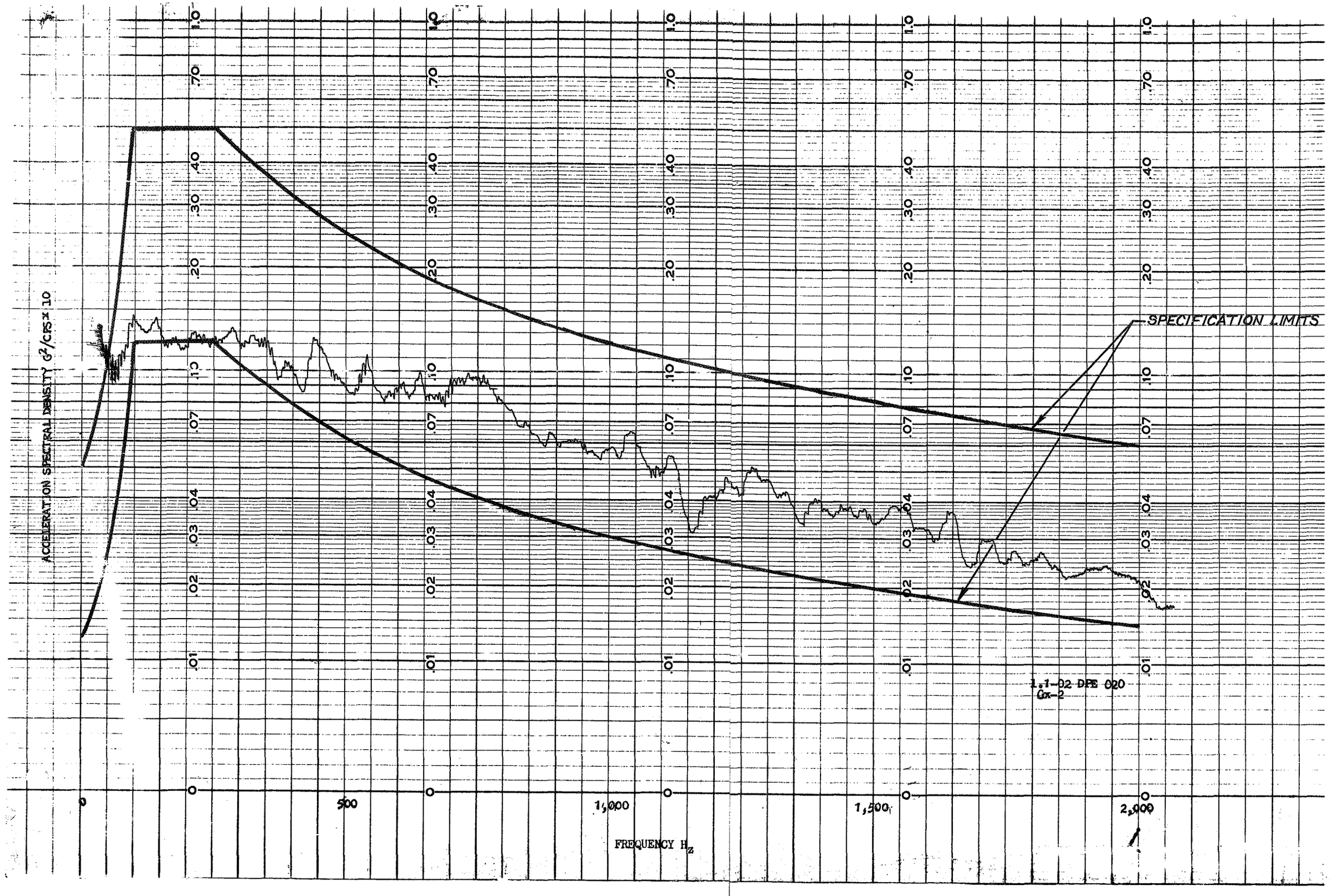


Figure 19, Vibration Data, Improper Tape Speed

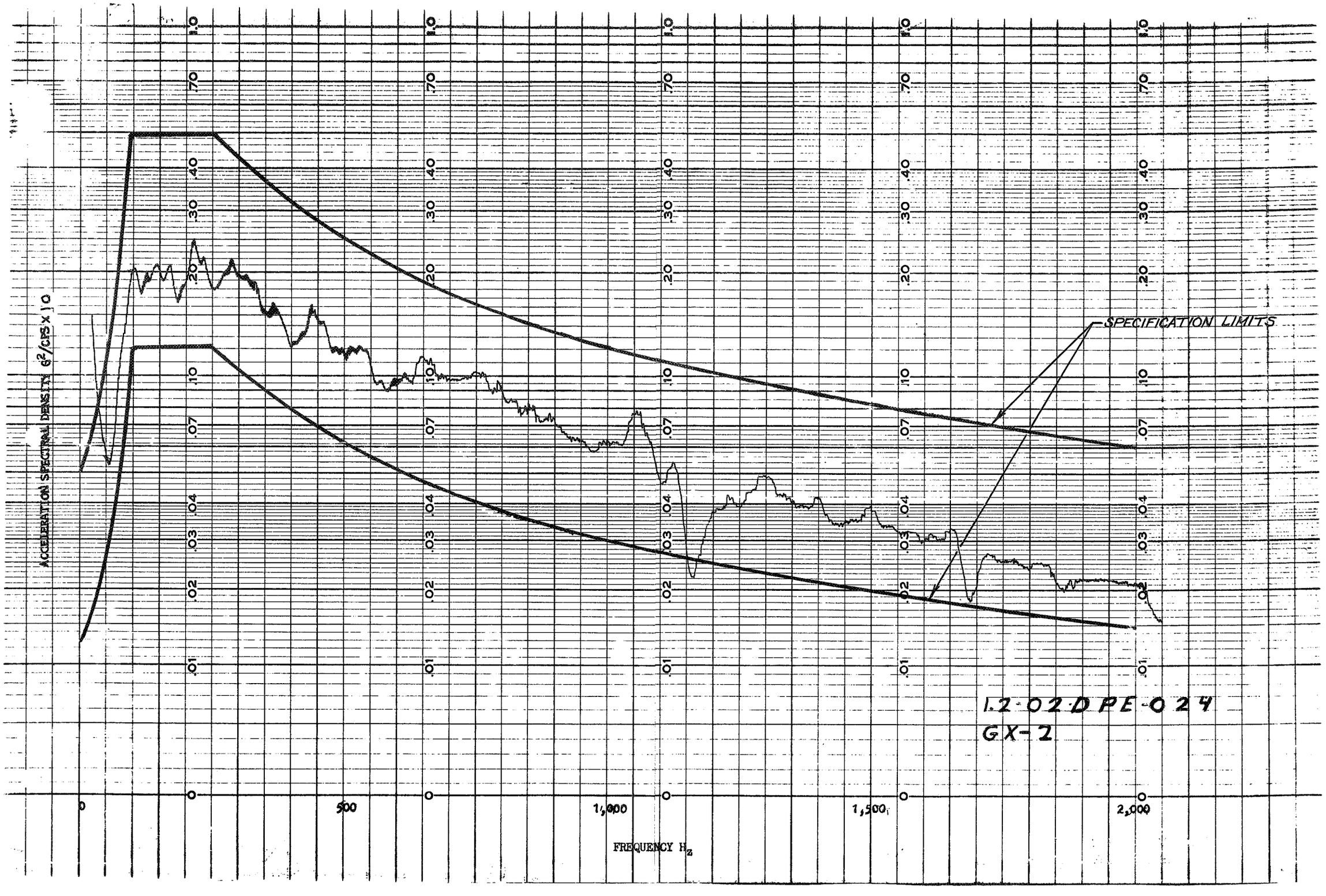


Figure 20, Vibration Data, Defective Equalizer

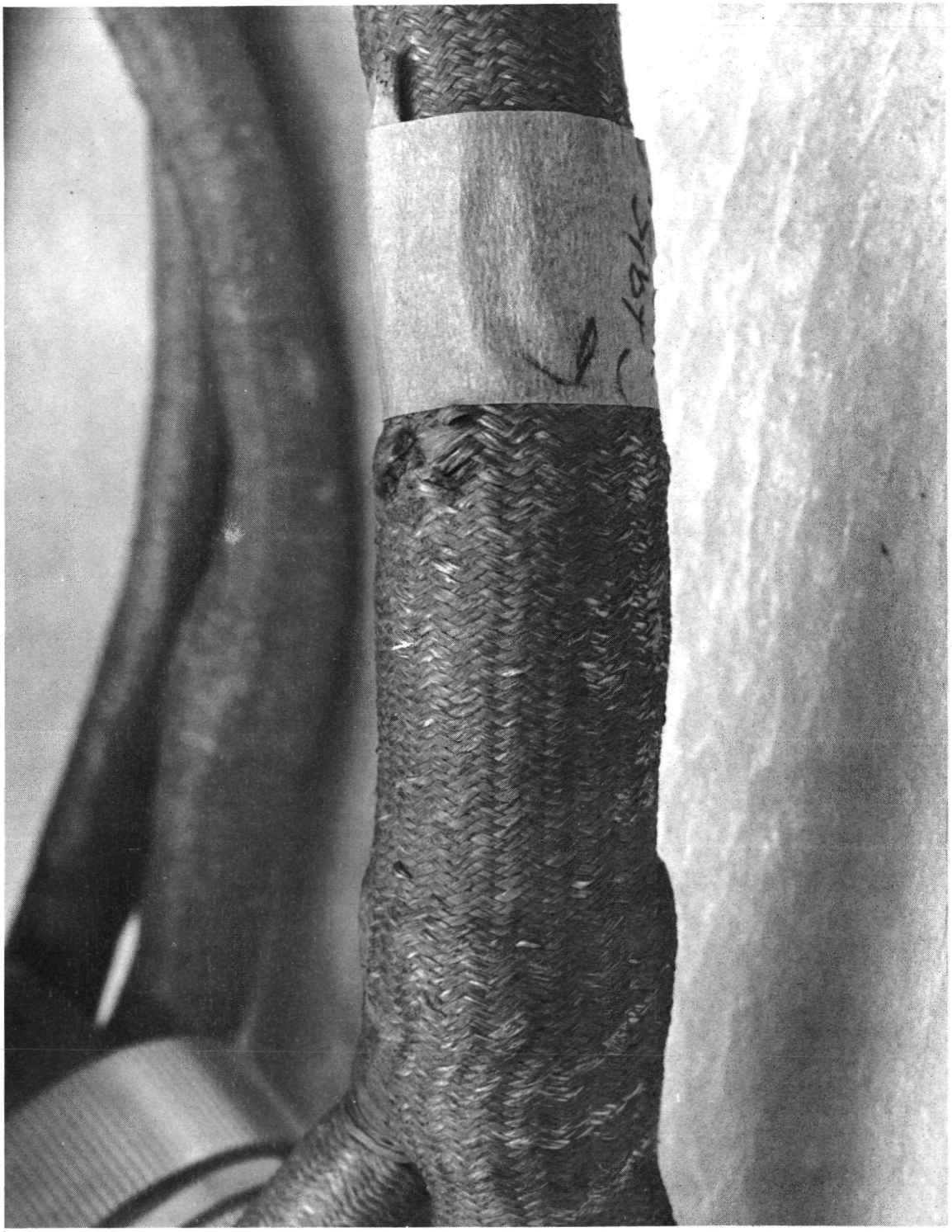


Figure 21, Fraying Damage, Top Harness

Figure 22, Connector Damage, Top Harness

Figure 23, Connector Damage, Bottom Harness

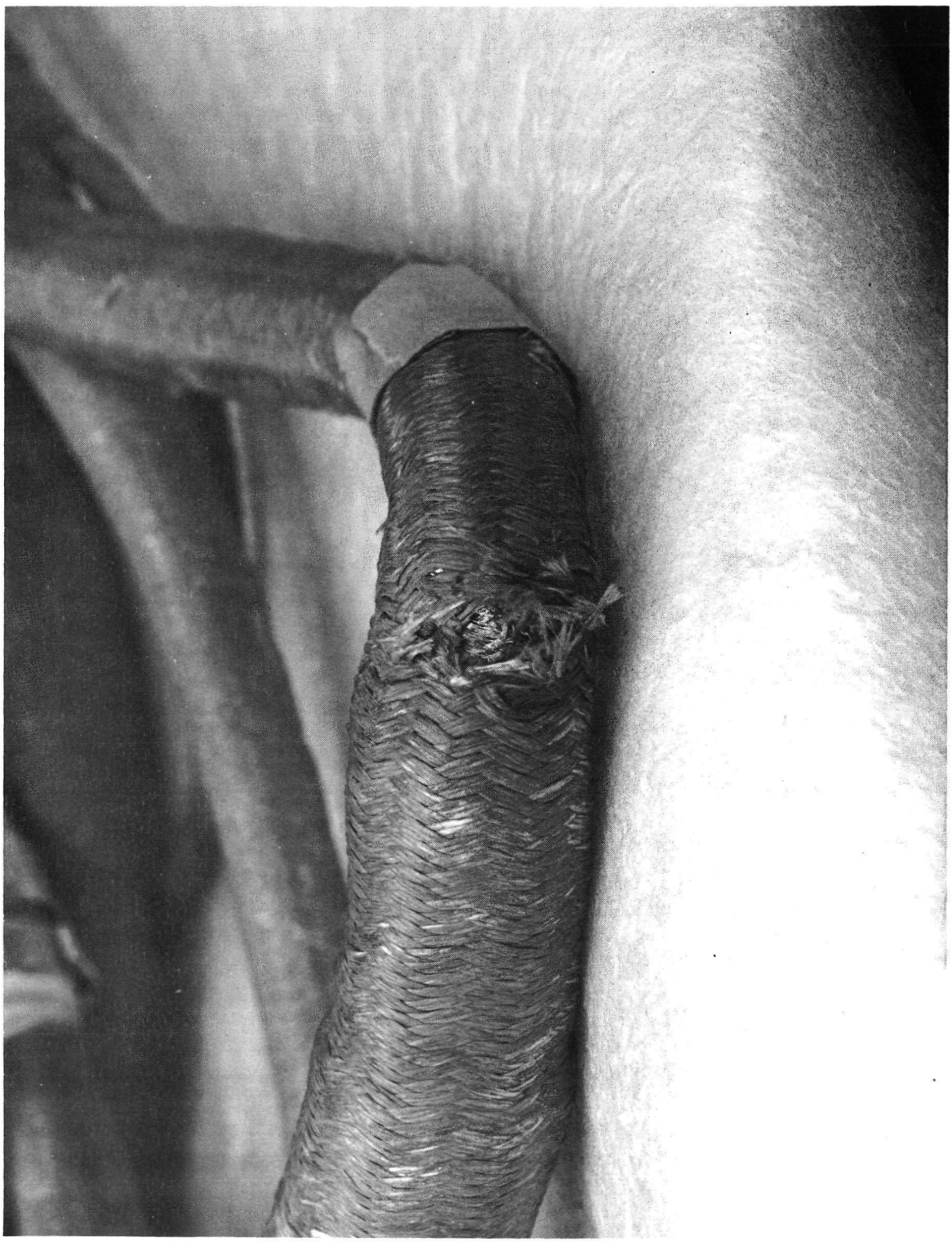


Figure 24, Fraying Damage, Bottom Harness

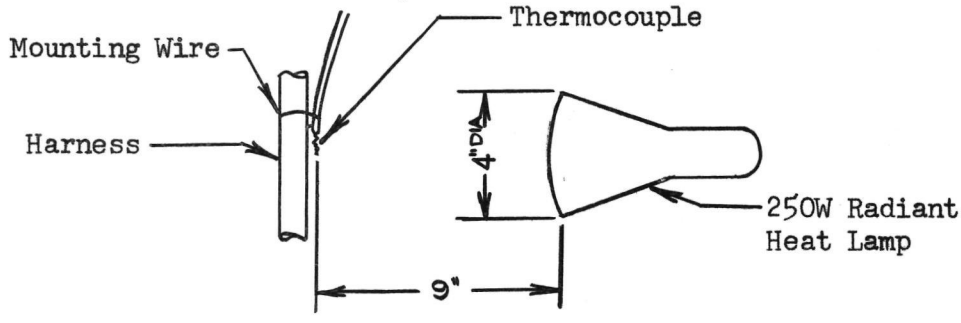
APPENDIX A

THERMAL ANALYSIS

THERMAL ANALYSIS

A. Purpose: The following analysis was conducted to determine the accuracy of harness temperature data obtained during the Phase IV test program utilizing thermocouples wired to the harness exterior in direct view of radiant heat lamps.

B. Basic Configuration:



C. Assumptions:

1. Lamp heat output per unit surface area is uniform.
2. Emissivity of thermocouple (ϵ_T) = .15
3. Absorptivity of thermocouple (α_T) = .15
4. Emissivity of harness (ϵ_H) = .70
5. Heat transfer from thermocouple (T) to harness (H) is by radiation only and shape factor of thermocouple to harness is 1.
6. Temperature differential across thermocouple is negligible.
7. Heat flux (q_L) from 250 watt lamp (L) = .24 BTU/sec.
8. Area of thermocouple (A_T) = .0253 in^2 (based on 2 wires of .0253" dia x $\frac{1}{2}$" long).
9. Harness temperature of interest is 200°F.

THERMAL ANALYSIS (cont.)

D. Analysis

1. Calculate shape factor of lamp to thermocouple (F_{L-T})

$$F = \frac{A_T F_{T-L}}{A_L} = \frac{.0253\ (.0247)}{\pi\ (2)^2} = .497 \times 10^{-4}$$

Where $$F_{T-L} = \frac{A_L}{\frac{1}{2} A_{sp}} = \frac{\pi\ (2)^2}{\frac{4\pi (9)^2}{2}} = .0247$$

When A_T = area of thermocouple

A_L = area of lamp

F_{T-L} = shape factor of thermocouple to lamp

A_{sp} = area of a 9" dia sphere

2. Calculate heat incident upon thermocouple (q_T)

$$q_T = F_{L-T}\ (q_L) = .497 \times 10^{-4}\ (.24) = 11.93 \times 10^{-6} \text{ BTU/sec}$$

When q_T = heat flux to thermocouple

q_L = heat flux from lamp

F_{L-T} = shape factor of lamp to thermocouple

3. Calculate heat absorbed by thermocouple ($q_{T\ absorb}$)

$$q_{T\ absorb} = \alpha_T q_T = .15\ (11.93 \times 10^{-6} = 1.79 \times 10^{-6} \text{ BTU/sec}$$

When $q_{T\ absorb}$ = heat absorbed by thermocouple

α_T = absorptivity of thermocouple

q_T = heat flux to thermocouple

THERMAL ANALYSIS (cont.)

4. Calculate heat transfer from thermocouple to environment (q_{Trad})

$$q_{Trad} = \sigma \varepsilon_T F_{T-E} A_T (T_T^4 - T_E^4)$$

$$= 3.4 \times 10^{-15} (.15)(1)(.0253) \left[(660)^4 - (530)^4\right]$$

$$= 1.43 \times 10^{-6} \text{ BTU/sec}$$

When σ = constant based on Stefan-Boltzmann Law and unit conversion factors

ε_T = emissivity of thermocouple

F_{T-E} = shape factor of thermocouple to environment

A_T = area of thermocouple

T_T = temperature of thermocouple

T_E = temperature of environment

5. Calculate heat transfer from thermocouple to harness

$$q_{T-H} = q_{T\ absorb} - q_{Trad} = (1.79 \times 10^{-6}) - (1.43 \times 10^{-6}) = .36 \times 10^{-6} \text{ BTU/sec}$$

6. Calculate harness temperature based on above heat transfer rate

$$q_{T-H} = \sigma E F_{H-T} (T_T^4 - T_H^4)$$

$$T_H = \left[T^4 - \frac{q_{T-H}}{\sigma E F_{H-T}}\right]^{\frac{1}{4}}$$

$$T_H = \left[(660)^4 - \frac{(.36 \times 10^{-6})}{(3.4 \times 10^{-15})(.141)(.0253)(1)}\right]^{\frac{1}{4}} = 635°R$$

when σ = constant based on Stefan-Boltzmann Law and unit conversion factors

$$E = \frac{1}{\frac{1}{\varepsilon_T} + \frac{1}{\varepsilon_H} - 1}$$

F_{H-T} = shape factor of harness to thermocouple

THERMAL ANALYSIS (cont.)

6. T_T = temperature of thermocouple

   T_H = temperature of harness

E. Conclusions:

1. Indicated error in using thermocouple reading for harness temperature is $T_T - T_H = 660 - 635 = 25°F$

2. If estimate of thermocouple emissivity is not valid, magnitude of error is still slight as an emissivity of .6 will result in only 31°F difference between thermocouple and harness temperature.

APPENDIX B

ACCEPTANCE TEST RESULTS

ACCEPTANCE TEST RESULTS

TEST: Dielectric Strength

PN: 712173

SN: 034

TEST DEVICE: Hi Pot Tester

TEST VOLTAGE: 1050 ± 20 VAC

ALLOWABLE CURRENT: 2 Milliampers

CONNECTOR P-18

PIN	PRETEST (ma)	POSTTEST (ma)
A	.20	.10
B	.20	.09
C	.20	.20
D	.20	.19
E	NS	NS
F	NS	NS
G	NS	NS
H	.15	.10
J	.15	.10
K	.20	.10
L	.20	.10
M	.15	.10
N	.20	.10
P	NS	NS
Q	NS	NS
R	NS	NS
S	NS	NS
T	NS	NS
U	NS	NS

CONNECTOR P-19

PIN	PRETEST (ma)	POSTTEST (ma)
A	.20	.08
B	.20	.07
C	.20	.07
D	.20	.07
E	NS	NS
F	NS	NS
G	NS	NS
H	.20	.07
J	.20	.07
K	.20	.08
L	.20	.08
M	.20	.08
N	.20	.09
P	NS	NS
Q	NS	NS
R	NS	NS
S	NS	NS
T	NS	NS
U	NS	NS

CONNECTOR P-1

PIN	PRETEST (ma)	POSTTEST (ma)
A	.20	.16
B	.20	.17
C	.20	.17
D	.20	.17
E	.30	.06
F	.30	.06
G	.30	.06
H	.30	.09
J	.90	.98
K	.20	.16
L	.20	.16
M	NS	NS
N	.20	.17
P	.20	.16
Q	.20	.15
R	.30	.03
S	.30	.08
T	.30	.06
U	.25	.09

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

CONNECTOR P-18

PIN	PRETEST (ma)	POSTTEST (ma)
V	NS	NS
W	NS	NS
X	.15	.20
Y	.15	.01
Z	.15	.01
a	.25	.24
b	.25	.10
c	.50	.10
d	.20	.02
g	.25	.19
h	.25	.10
j	.20	.20
k	.25	.10
l	.25	.02
m	.50	.02

CONNECTOR P-19

PIN	PRETEST (ma)	POSTTEST (ma)
V	NS	NS
W	NS	NS
X	.20	.09
Y	.20	.09
Z	.60	.27
a	.30	.01
b	.30	.01
c	.60	.27
d	.20	.09
g	.30	.01
h	.30	.01
j	.20	.08
k	.60	.27
l	.30	.01
m	.30	.01

CONNECTOR P-1

PIN	PRETEST (ma)	POSTTEST (ma)
V	.25	.06
W	.75	.42
X	.30	.05
Y	.25	.08
Z	.25	.08

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

TEST: Insulation Resistance — TEST DEVICE: Megohmmeter

PN: 712173 — TEST VOLTAGE: 500 VDC

SN: 034 — ALLOWABLE RESISTANCE: 100 Megohms min

CONNECTOR P-18			CONNECTOR P-19			CONNECTOR P-1		
PIN	PRETEST	POSTTEST	PIN	PRETEST	POSTTEST	PIN	PRETEST	POSTTEST
A	160K	22K	A	450K	∞	A	300K	20K
B	100K	22K	B	500K	∞	B	400K	22K
C	100K	∞	C	100K	∞	C	300K	∞
D	120K	∞	D	130K	∞	D	450K	∞
E	NS	NS	E	NS	NS	E	220K	∞
F	NS	NS	F	NS	NS	F	200K	∞
G	NS	NS	G	NS	NS	G	250K	∞
H	160K	∞	H	200K	∞	H	280K	∞
J	135K	∞	J	240K	∞	J	350K	16K
K	150K	∞	K	400K	∞	K	500K	∞
L	160K	∞	L	400K	∞	L	260K	∞
M	180K	∞	M	280K	∞	M	NS	NS
N	300K	∞	N	400K	∞	N	90K	∞
P	NS	NS	P	NS	NS	P	50K	∞
Q	NS	NS	Q	NS	NS	Q	30K	∞
R	NS	NS	R	NS	NS	R	90K	∞
S	NS	NS	S	NS	NS	S	120K	∞
T	NS	NS	T	NS	NS	T	200K	∞

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

CONNECTOR P-18

PIN	PRETEST	POSTTEST
U	NS	NS
V	NS	NS
W	NS	NS
X	120K	∞
Y	92K	∞
Z	40K	16K
a	40K	900K
b	45K	500K
c	45K	18K
d	35K	∞
g	30K	500K
h	30K	500K
j	45K	∞
k	45K	∞
l	45K	500K
m	60K	∞

CONNECTOR P-19

PIN	PRETEST	POSTTEST
U	NS	NS
V	NS	NS
W	NS	NS
X	100K	∞
Y	90K	∞
Z	75K	16K
a	65K	700K
b	65K	900K
c	60K	70K
d	65K	∞
g	60K	600K
h	60K	900K
j	65K	∞
k	60K	70K
l	40K	900K
m	45K	500K

CONNECTOR P-1

PIN	PRETEST	POSTTEST
U	150K	∞
V	200K	∞
W	250K	260K
X	200K	∞
Y	300K	∞
Z	525K	17K

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

TEST: Continuity

TEST DEVICE: Ohmmeter

PN: 712173

ALLOWABLE RESISTANCE: .5 ohms max

SN: 034

CIRCUIT	PRETEST	POSTTEST	CIRCUIT	PRETEST	POSTTEST	CIRCUIT	PRETEST	POSTTEST
P1A-P26A	.10	.06	P1N-P8A	.08	.05	P1h-P8h	.10	.06
B- B	.05	.06	P- B	.08	.05	j- j	.10	.06
C- C	.05	.07	Q- C	.08	.05	k- k	.05	.02
D- D	.07	.07	P18A-P20A	.05	.02	l- l	.10	.06
K- E	.08	.06	B- B	.05	.02	m- m	.10	.06
L- F	.08	.07	C- C	.05	.01	P19A-P21A	.05	.02
P1E-P4A	.07	.06	D- D	.05	.02	B- B	.05	.02
F- B	.08	.07	H- H	.08	.06	C- C	.05	.02
G- C	.10	.07	J- J	.08	.06	D- D	.08	.02
H- D	.10	.06	K- K	.10	.06	H- H	.08	.06
J- E	.05	.04	L- L	.10	.06	J- J	.08	.06
P1R-J24A	.10	.06	M- M	.10	.06	K- K	.10	.06
S- B	.10	.06	N- N	.10	.06	L- L	.10	.06
T- C	.10	.06	X- X	.10	.06	M- M	.10	.06
U- D	.10	.06	Y- Y	.10	.06	N- N	.10	.06
W- E	.10	.06	Z- Z	.08	.02	X- X	.08	.10
P1V-P5A	.10	.07	a- a	.10	.06	Y- Y	.08	.06
Z- B	.10	.06	b- b	.10	.06	Z- Z	.05	.02
Y- C	.10	.06	c- c	.08	.02	a- a	.08	.06
X- D	.10	.07	d- d	.10	.06	b- b	.10	.06
J- E	.05	.03	g- g	.10	.06	c- c	.05	.02

ACCEPTANCE TEST RESULTS (cont.)

CIRCUIT	PRETEST	POSTTEST
P19d-P21d	.10	.06
g- g	.10	.06
h- h	.10	.07
j- j	.10	.06
k- k	.05	.02
l- l	.10	.06
m- m	.10	.07

ACCEPTANCE TEST RESULTS (cont.)

TEST: Dielectric Strength

PN: 712174

SN: 034

TEST DEVICE: Hi Pot Tester

TEST VOLTAGE: 1050 ± 20 VAC

ALLOWABLE CURRENT: 2 milliamps max

CONNECTOR P-15			CONNECTOR P-14			CONNECTOR P-7		
PIN	PRETEST (ma)	POSTTEST (ma)	PIN	PRETEST	POSTTEST	PIN	PRETEST	POSTTEST
A	.20	.06	A	.20	.09	A	.20	.08
B	.20	.06	B	.20	.08	B	.20	.07
C	.20	.06	C	.20	.18	C	.20	.07
D	.10	.06	D	.20	.18	D	.20	.07
E	NS	NS	E	NS	NS	E	.25	.01
F	NS	NS	F	NS	NS	F	.20	.01
G	NS	NS	G	NS	NS	G	.25	.01
H	.15	.08	H	.15	.10	H	.25	.01
J	.20	.07	J	.20	.10	J	1.35	1.08
K	.15	.08	K	.20	.10	K	.20	.07
L	.15	.08	L	.20	.10	L	.20	.07
M	.20	.07	M	.20	.10	M	NS	NS
N	.15	.09	N	.20	.10	N	.20	.08
P	NS	NS	P	NS	NS	P	.20	.07
Q	NS	NS	Q	NS	NS	Q	.20	.06
R	NS	NS	R	.25	.18	R	.20	.01
S	NS	NS	S	.25	.02	S	.30	.01
T	NS	NS	T	.25	.01	T	.25	.02

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

CONNECTOR P-15			CONNECTOR P-14			CONNECTOR P-7		
PIN	PRETEST (ma)	POSTTEST (ma)	PIN	PRETEST	POSTTEST	PIN	PRETEST	POSTTEST
U	NS	NS	U	.25	.01	U	.30	.01
V	NS	NS	V	NS	NS	V	.30	.02
W	NS	NS	W	.10	.17	W	.80	.48
X	.20	.09	X	.20	.19	X	.30	.01
Y	.20	.09	Y	.20	.01	Y	.30	.01
Z	.55	.25	Z	.50	.01	Z	.30	.01
a	.30	.01	a	.25	.20			
b	.30	.01	b	.25	.10			
c	.55	.25	c	.50	.09			
d	.20	.10	d	.20	.01			
g	.25	.01	g	.25	.18			
h	.20	.01	h	.25	.09			
j	.20	.08	j	.20	.20			
k	.55	.24	k	.50	.09			
l	.25	.01	l	.25	.01			
m	.20	.01	m	.25	.02			

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

TEST: Insulation Resistance — TEST DEVICE: Megohmmeter

PN: 712174 — TEST VOLTAGE: 500 VDC

SN: 034 — ALLOWABLE RESISTANCE: 100 megohms min

CONNECTOR P-15

PIN	PRETEST (megohms)	POSTTEST (megohms)
A	350K	∞
B	500K	∞
C	∞	∞
D	∞	∞
E	NS	NS
F	NS	NS
G	NS	NS
H	∞	∞
J	∞	∞
K	450K	∞
L	300K	∞
M	350K	∞
N	800K	∞
P	NS	NS
R	NS	NS
S	NS	NS
T	NS	NS

CONNECTOR P-14

PIN	PRETEST (megohms)	POSTTEST (megohms)
A	∞	∞
B	∞	∞
C	∞	∞
D	∞	∞
E	NS	NS
F	NS	NS
G	NS	NS
H	500K	∞
J	300K	∞
K	400K	∞
L	200K	∞
M	280K	∞
N	500K	∞
P	NS	NS
R	∞	∞
S	∞	∞
T	∞	∞

CONNECTOR P-7

PIN	PRETEST (megohms)	POSTTEST (megohms)
A	500K	∞
B	450K	∞
C	500K	∞
D	450K	∞
E	400K	700K
F	300K	∞
G	400K	∞
H	500K	∞
J	54K	15K
K	500K	∞
L	300K	∞
M	NS	NS
N	450K	∞
P	500K	∞
Q	600K	∞
R	500K	∞
S	500K	∞

NS = not significant

ACCEPTANCE TEST RESULTS (cont.)

CONNECTOR P-15

PIN	PRETEST (megohms)	POSTTEST (megohms)
U	NS	NS
V	NS	NS
W	NS	NS
X	300K	∞
Y	300K	∞
Z	300K	20K
a	180K	∞
b	220K	∞
c	80K	22K
d	45K	∞
g	350K	∞
h	700K	∞
j	∞	∞
k	600K	25K
l	500K	∞
m	350K	900K

CONNECTOR P-14

PIN	PRETEST (megohms)	POSTTEST (megohms)
U	∞	∞
V	NS	NS
W	∞	∞
X	∞	29K
Y	∞	∞
Z	∞	∞
a	∞	26K
b	∞	∞
c	∞	∞
d	700K	∞
g	400K	∞
h	500K	∞
j	700K	29K
k	500K	∞
l	∞	∞
m	∞	∞

CONNECTOR P-7

PIN	PRETEST (megohms)	POSTTEST (megohms)
T	450K	∞
U	600K	∞
V	400K	∞
W	400K	18K
X	350K	∞
Y	350K	∞
Z	500K	∞

ACCEPTANCE TEST RESULTS (cont.)

TEST: Continuity

TEST DEVICE: Ohmmeter

PN: 712174

ALLOWABLE RESISTANCE: .05 ohms max

SN: 034

CIRCUIT	PRETEST	POSTTEST	CIRCUIT	PRETEST	POSTTEST	CIRCUIT	PRETEST	POSTTEST
P15A-P17A	.03	.02	P15j-P17j	.08	.07	P14c-P16c	.08	.02
B- B	.05	.02	k- k	.05	.03	d- d	.10	.06
C- C	.05	.03	l- l	.10	.07	g- g	.10	.06
D- D	.05	.03	m- m	.10	.07	h- h	.10	.06
H- H	.10	.07	P14A-P16A	.05	.02	j- j	.10	.06
J- J	.10	.07	B- B	.05	.02	k- k	.10	.03
K- K	.07	.07	C- C	.05	.02	l- l	.10	.06
L- L	.08	.07	D- D	.05	.02	m- m	.10	.06
M- M	.08	.07	H- H	.10	.05	P14R-J25A	.10	.06
N- N	.10	.07	J- J	.10	.05	S- B	.10	.06
X- X	.05	.07	K- K	.10	.06	T- C	.10	.06
Y- Y	.05	.07	L- L	.10	.06	U- D	.10	.06
Z- Z	.03	.03	M- M	.10	.06	W- E	.10	.07
a- a	.07	.07	N- N	.10	.06	P7A-P27A	.08	.06
b- b	.06	.07	X- X	.08	.06	B- B	.09	.06
c- c	.03	.03	Y- Y	.08	.06	C- C	.10	.06
d- d	.08	.07	Z- Z	.07	.03	D- D	.10	.06
g- g	.08	.07	a- a	.10	.06	K- E	.10	.06
h- h	.08	.07	b- b	.08	.06	L- F	.10	.06

ACCEPTANCE TEST RESULTS (cont.)

CIRCUIT	PRETEST	POSTTEST
P7E-P10A	.05	.06
F- B	.08	.06
G- C	.08	.06
H- D	.08	.06
P7J-P11E	.04	.03
V- A	.08	.07
X- D	.08	.07
Y- C	.08	.07
Z- B	.08	.07
P7N-P22A	.05	.05
P- B	.08	.05
Q- C	.10	.06
P7R-P23A	.08	.07
S- B	.08	.07
T- C	.08	.07
U- D	.08	.07
W- E	.08	.07
P10E-P11E	.08	
P7J-P10E		.04

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